UNITED STATES DEPARTMENT OF AGRICULTURE
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REPORT OF PROGRESS MADE IN 1938 ON WOOL SHRINKAGE PROJECT

-- SAMPLING CLIPS OF WOOL FOR SHRINKAGE DETERMINATION --

By Robert H. Burns
Senior Marketing Specialist

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Recognizing the need for more accurate knowledge concerning the different methods of sampling clips of wool for shrinkage determination, the Agricultural Marketing Service has undertaken a study of these different methods.

SHRINKAGE OF WOOL AND ITS COMMERCIAL APPLICATION

The layman had difficulty interpreting the term "shrinkage" as applied to wool for he usually thinks of shrinkage in its strictly physical sense. The shorn fleece of the sheep contains varying quantities of extraneous material such as sand, dirt, seeds, burrs, cactus, greasewood, paint, and indigenous material such as sweat, excreta, and grease.

The commercial value of a fleece or a clip of wool is controlled by the quantity of clean wool fiber that it yields. This weight of clean wool fiber as expressed by the percentage it makes up of the original weight of greasy wool, is spoken of as the "yield". When an allowance is made for the impurities remaining in the scoured wool after it is washed the term "clean content" is used to describe the clean wool which contains no impurities. The percentage of the original weight of greasy wool removed by scouring is spoken of as "shrinkage".

Shrinkage, in the trade, is based on the billed weight of grease wool, and the value of a clip or lot of wool cannot be ascertained until the shrinkage and grade are known or are estimated by competent wool handlers. In the past the producer has had very few sources of information available from which he could obtain an unbiased description of the shrinkages and grades of his clip. In recent years information has been available to him on the grade of his clip, but the information on shrinkage was largely conjectural and in most cases was biased in nature. In few, if any, cases could he obtain actual shrinkage figures on his clip, or on a part of it.

He has wanted in the first place a test of shrinkage on his clip that would give him information in time to be of use to him when he sells that clip. In the second place he is interested in collecting, over a period of years, information concerning the range in fleece weights, grade and shrinkage of his clip. He then has the information necessary to outline his program of wool improvement, taking into consideration the various feed and climatic conditions which influence his wool clip in connection with the breeding policy which is being followed.

1/ This report was prepared by Dr. Burns when he was in charge of the wool shrinkage project, which was formerly under the supervision of the Bureau of Agricultural Economics. Effective July 1, 1939 this work was transferred to the newly created Agricultural Marketing Service.

REVIEW OF EXPERIMENTAL TESTS IN SAMPLING FOR SHRINKAGE DETERMINATION

A very limited number of tests have been made of the shrinkage of samples of wool as compared with entire lots. During the World War, Dantzer (1922) made a series of tests for the French Government in which he compared the shrinkage of small samples against entire lots. He tested four 500-gram (1.1 pound) samples drawn from a lot of wool weighing 48,044 pounds. The samples gave a shrinkage of 43.4 percent while the figure for the entire lot was 51.4 percent, a difference of around 8 percent. It is rather interesting that the estimates of expert wool handlers were in error by around 6 percent on the same lot of wool. The method of obtaining the samples is not mentioned but it is stated that they were representative.

Jones and Lush (1927) reported the shrinkage of fleeces as compared with entire lots, working with fine wool fleeces. They reported that 25 fleeces give a shrinkage within 2 percent of the actual shrinkage if the fleeces are selected by a fair method. By increasing to 100 fleeces the average shrinkage is within 1 percent of the actual. Each of four different methods of sampling which they tested gave reliable results. These four methods all used entire fleeces and were based on mechanical selection. In these four methods of mechanical selection the fleeces were selected: from 20 sheep cut out of the flock, from 10 sheep cut out of the flock, every 5th fleece, and every 10th fleece.

Spencer, Hardy, and Brandon (1928) of the Bureau of Animal Industry, U. S. Department of Agriculture, made a study of the shrinkage of wool taken from the side area of fleeces as compared with the entire fleeces. Ninety-eight fine wool fleeces were included in this study and the shrinkage of the side samples was 56.80 percent, while that of the entire fleeces was 56.95 percent.

Wilson (1929) made some tests of small composite samples taken in triplicate. These samples varied about 3 percent from each other. He included that these samples were too small to represent accurately the clip samples, and that the 3-pound samples which were used would not give as accurate results as if 10-pound samples had been used.

Burns (1931) reported some shrinkage tests in which duplicate samples, taken from two different groups of 50 fleeces gave satisfactory results insofar as indicated by the correspondence of the two samples. These samples varied from each other by less than 2 percent.

Wilson (1931) reported a test of three 6 to 7-pound samples made up by separating handfuls of wool at random in triplicate from each of 47 fleeces before they were tied. Three subsamples of about 200 grams (0.44 pound) were taken from each of the larger samples and scoured separately. The subsamples agreed in shrinkage, but the larger samples varied by 3 percent which was considered as too large a difference. The author concluded that an accurate method of sampling each fleece must be found before any reliable index of the shrinkage of a clip could be determined.

Buck and Wood (1936) of the Agricultural Marketing Service, U.S. Department of Agriculture, made a comparison of the shrinkage of side samples against entire fleeces. Forty-nine range fleeces and 50 farm fleeces awere used. The average shrinkage of the entire fleeces was 61.86 percent as compared with 61.55 percent for the side samples.

PRESENT STATUS OF THE PROBLEM OF SAMPLING FOR SHRINKAGE DETERMINATION

At the present time, important and far reaching changes are taking place in the structure of the wool-marketing system in this country. The growers have become dissatisfied with the service rendered by the wool commission firms, particularly in regard to the methods used in handling consignment lots. There has been a marked increase in the quantity of wool purchased in the country for direct shipment to the mills and top makers. The top makers have increased their business to take care of the demand from the manufacturers who would rather depend on the top maker for a supply of wool than carry quantities of wool in storage. The growers have shown increasing interest in cooperative selling associations, local warehouses, and the auction sales which have been started by a private company in the producing areas. All of these contacts have increased the desire among the growers to know the factors that regulate the inherent market value of their wool clip. Consequently there has been a great increase of grower interest in the problem of grades and shrinkage.

DEVELOPMENT OF SAMPLING METHODS

There is a distinct lack of information concerning the shrinkage of a series of small samples as compared with an entire lot. The ultimate test of the shrinkage of a lot of wool is to find out how much extraneous and indigenous material is lost when the wool is scoured at the mill.

There are two means of obtaining a shrinkage of a large lot of wool by a representative sample. The first method is by the use of intact fleeces which represent the much larger number of fleeces in the entire clip or lot. The second method carries this step a little further and attempts to obtain representative handfuls either at random or from specific body areas in the fleece. The first method, using entire fleeces only, has one chance of variation due to the accuracy with which one fleece or a series of single fleeces represents a much larger number of fleeces in an entire lot. In the second method there is an additional chance of error in the selection of samples from the fleeces.

PRACTICAL ASPECTS OF WOOL SAMPLING

When commercial scouring plants are available the use of entire fleeces is desirable, for then one major source of variation has been removed, namely, the accuracy with which the small sample or samples represent each fleece. When commercial scouring plants are not available and quick results are desired the small-sample method has been used. The small sample method has been the most practical means of obtaining a quick test on the shrinkage of a clip of wool. In the past a large number of small samples, individual fleeces and sample bags of wool have been tested for shrinkage, but in very few instances was it possible to obtain a check on the sample, fleece, or bag shrinkages as compared with the mill yields of the entire clip.

The Agricultural Marketing Service has undertaken a research program, the object of which is to obtain representative samples of clips in the producing areas and to test a series of small samples or single composite bags against entire clips or lots of wool. It was hoped that it would be possible to follow through clips of wool that had been sampled at the ranch and obtain the yield of these lots when processed at the mill. But it was found that the lots generally lost their identity in the wool trade so it has not been possible to carry out this plan. It was necessary to sample certain lots of unknown identity at the mill and compare the shrinkage of these samples with that of the entire lots when processed.

METHODS OF PROCEDURE

Sampling Procedure at the Ranch

Composite Bags, Composite Samples, Grade-Pile Samples: The composite bag was made up in the same proportion as the different grades in a 10-bag sample which consisted of bags set aside at spaced intervals through the clip. In a few instances, where the clips were small, the growers laid aside fleeces at spaced intervals to make up a composite bag which represented their clip. The 10 bags of wool were graded out into their respective grade piles and the percentage by weight of each grade was calculated. The proportionate number of fleeces were then mechanically selected by chronological selection from each grade pile so that the composite bag as made up had the same composition by grade as the entire 10-bag lot. Hand samples were taken in duplicate by two operators from the shoulder, side, and back areas of each of the tied fleeces in the composite bag and these samples were known as composite samples. Other hand samples were taken in the same way from as many as 100 fleeces (depending on the number of fleeces in the grade pile) in each grade pile and these samples are referred to as grade-pile samples.

The composite bags were shipped to a commercial scourer in the East and the wool was scoured by sorts. The shrinkages were calculated on the basis of 13 percent of moisture which is the amount of moisture generally accepted as normal for average scoured wool. The composite samples and grade-pile samples were shipped to a wool laboratory of the Department where they were scoured. The wool in the composite samples had been separated by grade when they were made up. The shrinkages from these samples were also calculated on the basis of 13 percent of moisture.

Grading of each Fleece as Shorn: It was desirable to know the grade of the fleeces in the order that they went into the sacks to see whether a representative sample of the clip would be obtained by a mechanical method of selection. Each fleece in three different clips was graded and a chronological record of the grade of each fleece was kept, in the order that they went into the sack.

Fleece Sorts, Random and Side Samples: A limited amount of information is available concerning the shrinkage of the different body sorts, definitely located according to body areas, as compared with the entire fleece. It is important to know these relationships in order to make definite comparisons of the different systems used in selecting small samples.

During the shearing season of 1938 fleece-sorting work was carried on in cooperation with Gus Larson of Rawlins, Wyoming, the Montana Agricultural Experiment Station, and the U. S. Sheep Experiment Station of the Bureau of Animal Industry, at Dubois, Idaho. The original plan, with the Gus Larson fleeces, called for the selection of five fleeces from each grade of wool represented in the clip. However, it was not possible to obtain fleeces in all of the grades and 17 fleeces were obtained distributed as follows; Fine 5, 1/2 Blood 5, 3/8 Blood 4, and 1/4 Blood 3. These fleeces were split down the middle of the back; this left one "half" intact, and then the other half was divided into shoulder, side, back, belly, tags, and remainder.

At the Montana Agricultural Experiment Station the plan was to select enough fleeces from their fine-wool range flock to make up a bag of wool, and divide these fleeces before they were tied. The fleece was split down the back, one "half" was left intact and the other "half" was divided up into six body sorts. There were 23 Fine fleeces and three 1/2 Blood fleeces.

At the U. S. Sheep Experiment Station the plan was to obtain 5 ewe fleeces and 5 ram fleeces, as available from the four breeds and types of sheep at that station. Thirty-nine fleeces were obtained from that station to use in the fleece sort work. All fleeces were from yearling sheep.

Fleeces from 121 yearling ewes were obtained for use in the comparison of random and side samples and the entire fleece, in regard to shrinkage. These fleeces were obtained from the four different breeds and types and six black fleeces were also included. There were 30 Rambouillet fleeces, 25 Targhee fleeces, 30 Columbia fleeces and 30 Corriedale fleeces in the study of random and side samples. All fleeces were from yearling ewes.

The fleece sorts were made up in exactly the same method as used with the fleeces from the Gus Larson clip.

The following method was used in making up the side and random samples. As each fleece was shorn a large handful of the side wool was taken by one operator. When the fleece was tied another operator took a random sample from the fleece confining himself to the shoulder, side, and back wool. These two samples were sacked separately and the remainder of the fleece along with these two sacked samples, was placed in one of the large sample bags.

METHODS OF PROCEDURE

Sampling Procedure at the Mills and Warehouses

Random and Commercial Samples, 5-Bag Lots: Five clips, from which one band had been sampled at the shearing shed, were later located at the warehouse of the National Wool Marketing Corporation and cooperative arrangements were made to obtain 5-bag sample lots from each of these clips. Random and commercial samples were taken from each of the fleeces in these 5-bag lots by two different operators. The 5-bag sample lots were selected from the large clips by a commercial method. The random samples were taken by a method similar to that used at the shearing

shed in which handfuls of wool were pulled from the shoulder, side, and back portions of the fleece. The commercial samples were taken by the operators to represent their judgment of a representative sample of the 5-bag lot.

Random Samples, Entire Lots: In a second series of tests carried on in cooperation with a commercial mill a test lot of 10 bags was selected out of the entire lot, using equal spacing by number throughout the lot. These 10 bags were graded when necessary and samples were taken in duplicate from every fleece in the 10 bags. One lot consisted of 82 bags of Original Bag Wyoming and this lot graded out into Fine and 1/2 Blood with a sprinkling of 3/8 Blood. The latter grade was not used at the mill and hence was excluded from the test. The other two lots were graded lots of 1/2 Blood from Montana and Idaho. Each of the sublots contained approximately 10 bags. The following table shows the relationship of these lots, sublots, and the samples made up from the sublots:

Table 1. - Size of Lots, Sublots and Number of Samples.

	Entire Lot	Sublot	
	No. Bags	No. Bags	No. Samples
Wyoming, Original Bag	82	9	6
Montana, 1/2 Blood	126	10	24
Idaho, 1/2 Blood	258	10	12

The number of samples varied because of various studies made on the effect of different factors on sampling.

The samples were taken from the tied fleeces and then the different lots were sorted and the offsorts were taken off. The mill used only the main body sorts which amounted to 95 to 96 percent of the total by weight. The offsorts, including tags, were not scoured at this mill. In the Idaho lot the U. S. Department of Agriculture made a test of the shrinkage from a sample of the tag sort and the shrinkage of the samples was then corrected to allow for the tag sort. However, the sampling method used has always aimed to obtain representative samples from the shoulder, side, and back wool, which makes up the major body sorts of the fleece. So the samples coming from these body areas were directly comparable with the lots processed at the mill.

Laboratory Method of Scouring: The samples were passed through a wool duster and then were put through a semi-commercial scouring plant consisting of six bowls measuring 10 feet long, 18 inches wide and 18 inches deep. The first bowl contained a steeping solution consisting of 0.25 percent of textile soda and 0.10 percent of textile soap by weight. The second bowl contained a scouring solution consisting of 0.10 percent of soda and 0.50 percent of soap by weight. The third bowl contained 0.10 percent of soda but the concentration of soap was reduced to 0.25 percent by weight. The last three bowls contained rinse water. The wool was divided into portions of approximately 2,000 grams each. These portions were floated through the scouring liquor and fed through the squeeze rolls between each bowl

by hand. Each bowl was equipped with a perforated movable tray which would be raised up out of the solution. Thus the bits of wool that sank below the surface of the solution were caught on the tray and were not lost into the bottom of the bowl. The temperature of the different baths was kept at 120 degrees Fahr. When the wool came out of the last squeeze roll it was conveyed through a commercial-type drier at a temperature of 130 - 140° F. Then it was placed in containers and left to stand overnight to equalize the moisture conditions within the sample. The next day it was run through the duster and weighed. Subsamples were taken from each sample in proportion to the quantity of scoured wool in the sample. These subsamples were dried to constant weight in a conditioning oven. All final scoured weights were corrected to a basis of 12 percent of moisture. Tests were made on the cleanliness of the scoured wool by means of soxhlet and alcohol extractions and ashing on a number of samples (A.S.T.M. Designation D-232-36).

Scouring and Processing Procedure at the Mill: After the wool had been sorted at the mill and the weights had been obtained it was run through a commercial scouring machine and drier. Samples were taken of the scoured wool as it came from the drier and moisture determinations were made. Direct weights were taken and then the wool went on to the carding machines. The "scoured weight", which includes top, noil, slubbing and waste, was used in the calculation of the yield of the wool. Moisture determinations were made on the top and the top was also tested for grease content. All shrinkages were calculated on the basis of 12-percent moisture. The "scoured weight" included all of the scoured wool with very little loss. The variation of the moisture in the scoured wool as it came from the drier was so great that the shrinkage based on these figures was not used.

EXPERIMENTAL RESULTS

Composite Bags, Composite Samples, Grade-Pile Samples: During the 1938 shearing season 20 composite bags were made up from different clips. Samples were taken from each of the fleeces making up these composite bags. Results are given below:

Table 2. - The Shrinkage of Composite Bags and Duplicate Samples
(Tag Sort Excluded and Samples Included in Composite Bag Shrinkage)

Composite Bags Scoured by Commercial Scourer
Samples Scoured by A.M.S. Wool Laboratory

Shrinkages Based on 13% Moisture in Scoured Wool

	Composite Bag	Duplicate Samples From Composite Bag		
		Sample No. 1	Sample No. 2	Both
	66.2	63.6	63.4	63.5
	64.7	63.3	60.8	62.1
	66.2	63.6	63.7	63.7
	68.8	60.9	63.0	62.3
	68.2	65.6	65.6	65.6
	67.4	63.5	64.5	64.1
	68.2	65.9	61.0	63.4
	70.0	63.4	64.5	63.9
	63.5	62.3	62.2	62.3
	66.0	63.1	64.2	63.7
	66.8	65.9	64.1	64.8
	66.1	59.5	63.4	61.7
	63.7	62.0	62.0	62.0
	67.8	64.0	64.4	64.2
	60.7	57.7	58.5	58.1
	56.2	51.7	54.2	53.0
	61.5	59.2	58.8	59.0
	61.7	57.0	57.9	57.5
	65.0	62.7	61.5	62.1
	61.8	59.9	59.8	59.9
Mean	65.03	61.74	61.88	61.85

Difference between composite bag and composite samples 3.18

The shrinkages for the composite bags included the paper string used in tying the fleeces which of course was not included in the samples. The average quantity of paper string used in tying the fleeces in the 20 bags of wool amounts to 0.7 percent and this would reduce the difference between the shrinkages of the composite bags and the samples to 2.7 percent.

Table 3. - Table of Variance

Shrinkages of Composite Bags and Composite Samples

Variation Due to:	Degrees of Freedom	Sum of Squares
Clips or B ags	19	539.58267
Samples	1	15.75025
B oth Samples and Bags	1	138.03075
Interaction (a)	19	17.28475
Interaction (b)	19	26.54758
Total	59	737.19600

First comparison between samples and interaction
F 15.75025/17.28475 Equals 0.911 Not a significant difference.

Second comparison between samples and bags and interaction.
F. 138.03075/26.54758 Equals 5.20 a signigicant difference.

The analysis of variance indicates that the samples are not significantly different from each other, but are different from the bags. In a study of the interaction between both samples and the bags "t" equals 2.281 which is intermediate between the 5 and 1 percent levels at 19 degrees of freedom.

INFLUENCE OF THE TAG SORT ON THE SHRINKAGE OF THE COMPOSITE BAGS

The quantity of tags in each bag varied from 7 up to 62 pounds, and when the tag sort was removed in the calculation of the shrinkage the average difference amounted to around 1 percent as shown in table 4.

Table 4 - Shrinkage of Composite Sample Bags

Complete	Tag Sort Removed	
67.3	66.5	
65.4	64.9	
66.3	66.4	
69.1	69.1	
69.1	68.4	
68.3	67.6	
69.9	68.5	
70.8	70.4	
64.6	63.6	
67.1	66.2	
67.3	67.0	
67.1	66.3	
64.6	63.8	
69.4	68.0	
58.0	56.4	
62.8	60.9	
63.5	61.7	
63.3	61.9	
66.1	65.3	
63.7	62.4	
Mean 66.19	65.27	Difference 0.92

A Comparison of the Shrinkage of Composite Bag Sample and Grade-Pile Samples: Each composite bag was made up from the grade piles from 10 bags of wool selected at intervals through the clip. The composite bag contained the same proportion of each grade as the 10 bags. Samples were taken in duplicate from each fleece selected to go into the composite bag. Samples were also taken from each fleece in each of the grade piles. The grade piles made up from 10 bags of wool contained varying numbers of fleeces of each grade, from a few fleeces up to approximately 100 fleeces. It is interesting to compare the shrinkages of the composite-bag samples and the grade-pile samples.

Table 5.- Shrinkages of Small Samples (10-15 lbs. in Weight)

From Composite Bag	From Grade Piles
63.5	63.9
62.1	64.5
63.7	64.5
62.3	64.3
65.6	65.4
64.1	67.7
63.4	65.1
62.3	63.1
63.7	65.2
64.8	63.5
61.7	64.4
62.0	62.6
64.2	65.4
53.0	55.0
59.0	61.0
Mean 62.36	63.71

Difference 1.35

The results shown in Table 5 indicate that the grade-pile samples gave a higher shrinkage than the composite-bag samples. There were only two composite-bag samples as compared with a number of grade-pile samples which varied according to the number of fleeces in the 10 bags of wool from which the grade piles were made up. The grade pile samples give valuable information on the shrinkage of a clip, in addition to that obtained from the composite-bag and composite-bag samples.

Variation in Grade of Fleeces as Shorn and its Relation to Sampling Procedure.

During the shearing season of 1938, a study was made of the variation of the grades of the fleeces in a clip in relation to the sampling method. The object of these studies on three different clips was to find out how representative different sublots of wool were to the entire clip in respect to the grade of wool. Each fleece in these three clips was weighed and graded as it came to the sacking stand.

Table 6. - Percentage of Grades by Weight in Entire Clip and in Subdivisions

Clip No.1 : 5,320 Fleeces, or 97 Bales

Grade	Entire Clip	10 Bales or Every 10th Bale 1/	5 Bales or Every 20th Bale 2/	Every 10th Fleece
Fine	64.4	65.0	70.2	65.6
1/2 Blood	25.0	25.1	23.9	22.7
3/8 Blood	9.0	8.2	3.9	10.5
1/4 Blood	1.5	1.5	1.6	1.2
Low 1/4 Blood	0.1	0.2	0.4	0.0
All Grades	100.0	100.0	100.0	100.0

1/ 10 bales or every 10th bale amount to the same in a 100-bale clip.
2/ 5 bales or every 20th bale amount to the same in a 100-bale clip.

In this clip, 10 bales, every 10th bale, or every 10th fleece gave equally good representation of the clip in respect to the percentage of grades. However, when only five bales were selected at equal intervals throughout the clip the percentage of grades was not representative of the entire clip.

Table 7. - Percentage of Grades by Weight in Entire Clip, Subdivisions and in Composite Bag

Clip No. 2: 8,376 Fleeces, or 203 Bags

Grade	Entire Clip	10 Bags	Every 10th Bag	Composite Bag 3/
Fine	82.8	80.8	82.5	72.9
1/2 Blood	16.2	17.4	16.1	27.1
3/8 Blood	0.9	1.6	1.0	0.0
1/4 Blood	0.1	0.2	0.4	0.0
All Grades	100.0	100.0	100.0	100.0

3/ The composite bag was made up by selecting fleeces at equal intervals of time throughout shearing.

Again we find in Clip No. 2 that every 10th bag gives the best representation of the clip in regard to the grades of the fleeces. The composite bag containing the fleeces that were selected at equal intervals of time throughout the shearing of the clip did not give as representative results of the grades of the fleeces in comparison with the entire clip as did the other methods of sampling. Ten bags spaced at equal intervals throughout the clip did not give as good a representation of the clip as 20 bags made up by selecting every 10th bag.

Table 8. - Percentage of Grades by Weight in Entire Clip, Subdivisions and Composite Bag

Clip No. 3: 7,649 Fleeces, or 204 Bags

Grade	Entire Clip	10 Bags	Every 10th Bag	Composite Bag 1/
Fine	80.0	80.0	77.7	80.1
1/2 Blood	17.8	17.5	19.5	19.9
3/8 Blood	2.0	1.9	2.3	0.0
1/4 Blood	0.2	0.6	0.5	0.0
All Grades	100.0	100.0	100.0	100.0

1/ The composite bag was made up by selecting fleeces at equal intervals of time throughout shearing.

In Clip No. 3 both the 10-bag lot and every 10th bag (20-bag lot) gave a good picture of the entire clip in respect to grades. The composite bag gave a good representation in the Fine and 1/2 Blood grades, but did not contain any 3/8 Blood and 1/4 Blood fleeces.

Results in all three clips indicate that it does not seem to make much difference whether the method used is to select every 10th bag or to select 10 bags at equal intervals throughout the clip, insofar as obtaining a representative quantity of the different grades is concerned. Either method seems to give about as good results as the selection of fleeces at spaced intervals throughout shearing to make up 10 bags of wool. Furthermore the indications are that the selection of less than 10 bags of wool from a clip does not give satisfactory results when the percentages of the grades in the sublot are compared with the percentages in the entire clip.

The manner in which sheep come on to the shearing floor had a considerable effect on the order in which the different grades of fleeces went into the bags. It has been a common observation at the shearing pens that the coarse-wooled sheep are bolder and tend to be in the lead when the sheep go into the shearing pens, while the fine-wooled sheep tend to hang back.

Information is available on this observation through the percentage of grades from the first and last bags sacked from each band shorn.

Table 9. - Percentage of Total by Weight

Clip No. 1: 3 Bands, or 97 Bales

Band and Grade	First Bag of Band	Last Bag of Band
	%	%
Band No. 1:		
Fine	23.1	59.4
1/2 Blood	46.6	26.1
3/8 Blood	27.7	12.6
1/4 Blood	2.6	1.9
Band No. 2:		
Fine	46.8	75.0
1/2 Blood	43.1	18.6
3/8 Blood	8.4	6.5
1/4 Blood	1.7	0.0
Band No. 3:		
Fine	48.0	68.0
1/2 Blood	36.1	20.9
3/8 Blood	13.4	11.1
1/4 Blood	2.5	0.0
All Three Bands: 1/		
Fine	38.8	67.0
1/2 Blood	42.2	22.1
3/8 Blood	16.8	10.2
1/4 Blood	2.2	0.7

1/ Weighted Average.

The first bag of wool sacked from each band of sheep was consistently coarser in grade than the last bag of wool sacked from the same band. This tendency was very marked in all three of the bands of sheep in this clip.

Table 10. - Percentage of Total by Weight

Clip No. 2: 7 Bands, or 203 Bags

Band and Grade	First Bag of Band	Last Bag of Band
	%	%
All 7 Bands:		
Fine	78.2	84.8
1/2 Blood	20.0	14.0
3/8 Blood	1.8	0.9
1/4 Blood	0.0	0.3

The tendency for the coarser wooled sheep to forge ahead and come on to the shearing floor first is indicated by the higher percentage of the coarser grades in the first bag of the band. But some considerations apparently modify this relationship. Evidently in some cases the more advanced age of the sheep, irrespective of the grade of its wool, tends to make it hang back and come in with the last of the band.

Table 11. - Percentage of Total by Weight

Clip No. 3: 6 Bands, or 204 Bags

Band and Grade	First Bag of Band	Last Bag of Band
	%	%
All 6 Bands:		
Fine	84.4	80.9
1/2 Blood	15.0	17.5
3/8 Blood	0.6	1.6

The particular clip represented by table 11 contained fleeces from a considerable number of older "black-face" sheep. Evidently these older sheep with coarser fleeces tended to hang back along with the fine-wooled ones. When the ages of the sheep were about equal there seemed to be a strong tendency for the fleeces of the coarser wooled sheep to be represented in the first bags sacked from a band and the fleeces of the finer-wooled sheep were found in greater numbers in the last bags made up from a band.

Grease Content of Scoured Wool

The grease content of commercially scoured wool, according to the trade, varies between 0.50 to 0.75 percent. Tests of the grease content were made of the scoured wools in the mill lots and the samples scoured at the Agricultural Marketing Service laboratory. Results are found in table 12.

Table 12. - Grease Contents of Scoured Wool in Percent

Origin and Grade	Mill Lots		A.M.S. Samples
	Entire Lot	Sublot	
	%	%	%
Wyoming Original Bag	0.86	- -	0.93
Montana Graded 1/2 Blood	0.66	0.40	--
Idaho Graded 1/2 Blood	0.41	0.32	0.61

The grease content of the various scoured wools varied from 0.32 up to 0.93 percent. This considerable variation in the grease content of scoured wools shows that further work will need to be carried out to determine the normal grease content of scoured wool. The correction of shrinkages to a standard grease content of scoured wool (0.5 percent) makes a change in the original shrinkage of barely 0.1 of a percent.

Variation in Shrinkage Between Four Samples from the Same Fleece

As has been mentioned in connection with sampling procedure, some tests were made on the variation in shrinkage between four samples from the same fleeces, in the lot of Montana wool of graded 1/2 Blood, which was the second lot tested at the mill. Two operators took quadruplicate samples from each fleece, each operator going over the 50 fleeces represented in each sample, twice. All of the odd-numbered samples in the series of samples were taken by one operator and the even-numbered samples in the series were taken by the second operator. Thus samples No. 1 and 3 were taken from one set of 50 fleeces by one operator and Samples No. 2 and 4 were taken from the same set of 50 fleeces by the second operator. Two factors were studied in this test; the possibility of variation in shrinkage of samples selected by different operators and the variation in shrinkage between the first and last of four samples taken from the same fleeces. The results obtained are shown in the following table.

Table 13. - Shrinkages of Samples Taken by Two Operators

Samples by Sets of 4	Operator No. 1	Operator No. 2	Difference
	%	%	%
Set 1	58.3	57.8	- 0.5
" 2	60.2	59.3	- 0.9
" 3	59.5	60.5	+ 1.0
" 4	61.3	60.4	- 0.9
" 5	60.4	60.0	- 0.4
" 6	59.8	58.7	- 1.1

The difference in the shrinkage of samples selected by different operators is not significant statistically for "t" equals 1.49, which is smaller than the 5 percent level at 5 degrees of freedom.

An additional study was made of the variation found in the shrinkage of the first and last of four samples taken from the same fleeces. The question under consideration was whether repeated sampling of the same fleece would show any change in the shrinkage of the samples drawn. In this test four samples were taken from each of the same fleeces by two different operators. The results are shown in table 14.

Table 14. - Shrinkages of First and Last Samples Taken

Samples by Sets of 4	Sample No. 1	Sample No. 4	Difference
	%	%	%
Set 1	58.2	57.5	- 0.7
" 2	60.1	59.3	- 0.8
" 3	59.7	60.3	+ 0.6
" 4	61.3	60.1	- 1.2
" 5	60.4	59.5	- 0.9
" 6	60.3	60.0	- 0.3

The difference in shrinkage between the first and last of four samples taken from the same fleeces in this study was not significant for "t" equals 2.12, which is smaller than the 5-percent level for 5 degrees of freedom.

Comparison of the Shrinkage of Different Body Sorts and the Entire Fleece

Three separate lots of fleeces were tested and the shrinkages were obtained on six different body sorts obtained from one "half" of the fleece, while the other "half" of the fleece was scoured intact.

Table 15. - Percentage of Shrinkage by Fleece Sorts and Grade

Based on Laboratory Weights of Grease Wool and 13% Moisture in Scoured Wool

Lot No. 1

Grade	Fine	1/2 Blood	3/8 Blood	1/4 Blood	All Grades [1]
No. of Fleeces	5	5	4	3	17
FLEECE SORTS:					
Shoulder	63.7	52.7	53.1	49.7	55.5
Side	63.4	62.0	63.2	54.8	61.6
Back	70.8	64.0	61.6	57.3	64.4
Shoulder, side and back	-	-	-	-	62.4
Belly	57.4	55.8	59.7	46.5	55.8
Tags	83.0	82.0	84.2	76.3	82.2
Remainder	59.4	53.3	58.7	48.0	54.5
Total 1st half	66.9	61.0	62.8	54.4	61.9
Intact 2nd half	68.5	60.6	61.2	55.7	62.0
Entire Fleece	67.6	60.8	62.0	55.0	61.9

1/ Weighted average.

In the Fine fleeces the back sort is the closest in shrinkage to that of the entire fleece. In the 1/2 Blood fleeces the side was the closest. In the 3/8 Blood fleeces the back sort was the closest. In the 1/4 Blood the side was again the closest. In several instances the differences in the shrinkages of the shoulder, side, and back sorts

from the entire fleece were very close to each other and it will be noticed that in the case of all grades the side sort was almost identical in shrinkage to that of the entire fleece. It will also be noticed that the shrinkages of the two " halves" of the fleece were close together, even though one "half" was split up into differentsorts and the other "half" was kept intact. The fact that neither "half" of the fleece was consistently lower or higher in shrinkage than the other indicates that the distribution of the shrinkages of the "halves" was a random one and it made little difference which half was divided up. These results confirm the biological condition of unilateral development in animals in which one side is identical with the other.

The shrinkage of the shoulder, side, and back sorts considered as a single unit amounted to 62.4 percent, which is higher than the shrinkage of the entire fleece. This was due to the excessively high shrinkage of the back sort. This lot No.1 consisted of typical range fleeces from sheep that grazed in a sandy and windy country.

It is interesting to compare the percentage by weight of each of the body sorts as compared with the total half fleece that was sorted.

Table 16.- Lot No. 1
Percentage by Weight of Total Half Fleece

Grade FLEECE SORT:	Fine	1/2 Blood	3/8 Blood	1/4 Blood	All Grades
Shoulder	9.9	6.9	7.1	11.3	8.4
Side	21.6	20.2	18.4	19.3	20.0
Back	43.3	38.3	38.4	38.1	39.1
Belly	6.2	5.4	7.2	6.4	6.2
Tags	5.9	6.0	9.6	6.1	6.9
Remainder	13.1	23.2	19.3	21.8	19.4
Total	100.0	100.0	100.0	100.0	100.0

The shoulder, side, and back sorts of Lot No. 1 make up a very large percentage (67.5) of the total half fleece which was sorted.

The relation of the shoulder, side,and back portions to the entire half fleece for all three sorts gives information of value in setting up rules for takinga random sample from these major body areas in the tied fleece. For lot No. 1 all grades, the percentages for these three body sorts were shoulder 12.5, side 29.6 and back 57.9. In other words in fleeces of this kind around 1/8 of the handful from the tied fleece should come from the shoulder, 2/8 from the side, and 5/8 from the back.

The first half of the fleece which was sorted was heavier in weight in all grades than the second, or intact half (52.4 as compared with 47.6 percent).

Table 17.- Percentage of Shrinkage by Fleece Sorts and Grade

Based on Laboratory Weight of Grease Wool
and 13% Moisture in Scoured Wool

Lot No. 2

Grade	Fine	1/2 Blood	All Grades 1/
Number of Fleeces	23	3	26
Fleece Sorts:			
Shoulder	45.0	40.2	44.5
Side	51.3	49.8	51.2
Back	57.1	55.9	57.0
Shoulder, side & back	-	-	53.4
Belly	56.9	58.5	57.1
Tags	78.2	76.3	77.8
Remainder	50.2	45.0	49.5
Total first half	53.5	51.7	53.3
Intact second half	53.3	52.7	53.2
Entire fleece	53.4	52.1	53.3

1/ Weighted Average.

In all cases the side sort in Lot No. 2 was the closest to the shrinkage of the entire fleece, but the difference ran around 2 percent, the side samples being lighter in shrinkage than the entire fleeces. However, the combination of shoulder, side, and back sorts gave a shrinkage of 53.4 which was almost identical with that of the entire fleece.

Table 18.- Percentage by Weight of Total Half Fleece

Lot no. 2

Grade	Fine	1/2 Blood	All Grades
Fleece Sorts:			
Shoulder	6.1	5.7	6.1
Side	29.9	30.7	30.0
Back	33.6	31.7	33.3
Belly	10.7	10.5	10.7
Tags	0.9	1.8	1.0
Remainder	18.8	19.6	18.9
Total	100.0	100.0	100.0

The shoulder, side, and back sorts made up 69.4 percent of the total half fleece which was sorted in the case of Lot No.2

The relation of the shoulder, side, and back portions as compared with the total for all three sorts gives information on the proportions of wool that should be taken from each body area (sort) when sampling from tied fleeces. For all grades in Lot No.2, the percentages by weight

for these three body sorts were shoulder 8.8, side 43.2, and back 48.0. In fleeces of this type the proportions taken from the different body sorts in the tied fleece would be around 9 percent from the shoulder, 43 percent from the side, and 48 percent from the back.

The first half fleece that was sorted is again heavier in weight than the second or intact half fleece (54.3 as compared to 45.7 percent).

Table 19.- Percentage of Shrinkage by Fleece Sorts and Breeds

Based on Laboratory Weight of Grease Wool and 13% Moisture in Scoured Wool

Lot No. 3

	Percent of Shrinkage				
Breed	Rambouillet	Targhee	Corriedale	Columbia	All Breeds 1/
No of Fleeces	10	10	9	10	39
Fleece Sort:					
Shoulder	52.6	51.2	47.9	45.7	49.5
Side	55.3	55.3	51.3	46.2	52.3
Back	55.1	56.7	52.8	49.2	53.5
Shoulder, side, back	54.9	55.5	51.5	47.7	52.5
Belly	62.4	62.9	59.8	59.5	61.3
Tags	81.3	83.7	76.8	80.5	80.4
Remainder	55.9	54.3	50.1	49.1	52.4
Total 1st half	56.7	56.8	53.0	50.5	54.3
Intact 2nd half	56.8	56.8	52.9	50.5	54.3
Entire fleece	56.7	56.8	53.0	50.5	54.3

1/ Weighted Average

In all of the breeds except the Rambouillet (and even there the difference is very small), the back sort was the closest to the entire fleece in shrinkage. The difference in shrinkage between the back area and the entire fleece was very small, being less than 1 percent, in all breeds. The first and second halves were almost identical in shrinkage.

Table 20.- Percentage by Weight of Total Half-Fleece

Lot No. 3

Breed	Rambouillet	Targhee	Corriedale	Columbia	All Breeds 1/
Fleece Sort:					
Shoulder	7.1	7.0	7.4	6.5	7.0
Side	19.8	18.7	18.8	16.9	18.6
Back	26.1	27.4	24.8	26.5	26.2
Belly	11.5	10.9	10.6	9.5	10.6
Tags	2.5	3.2	4.4	3.3	3.3
Remainder	33.0	32.8	34.0	37.3	34.3
Total	100.0	100.0	100.0	100.0	100.0

1/ Weighted Average.

The shoulder, side, and back sorts of Lot No. 3 made up 51.8 percent of the total half-fleece when sorted. The remainder portion of the fleece which consisted of britch, dock, hip, neck, head, and legs amounted to much more in these fleeces than in the other two lots; and conversely the shoulder, side, and back sorts were smaller than in the other lots (51.8 against 69.4 and 67.5). These three lots show the great variation in the quantities of the different fleece sorts according to the condition of the fleece and the bulkiness of it, dependent upon the size of the sheep on which the fleece was grown. The Columbia is the largest and most robust of the breeds of sheep in Lot No. 3, and this breed shows a large percentage by weight in the back and remainder sorts.

The relation of the shoulder, side, and back sorts to the total of the three sorts gives information of value in taking samples from tied fleeces. In Lot No. 3 for all breeds the percentage by weight for these three sorts was shoulder 13.4, side 35.9, and back 50.7. The proportions to be taken from tied fleeces similar to those in Lot No.3 would be around 13 percent from the shoulder, 36 percent from the side, and 51 percent from the back.

The comparison of the different fleece sorts with the entire fleece in respect to shrinkage gives some interesting results when all three lots are listed together.

Table 21.- Shrinkages by Fleece Sorts for all Grades and Breeds

Based on Laboratory Weight of Grease Wool
and 13% Moisture in Scoured Wool

Lots No. 1, 2 and 3

Fleece Sorts	Percent of Shrinkage			
	Lot No.1	Lot No.2	Lot No.3	All Lots
Shoulder	55.5	44.5	49.5	49.8
Side	61.6	51.2	52.3	55.0
Back	64.4	57.0	55.5	58.3
Shoulder, Side and Back	62.4	53.4	52.5	56.0
Belly	55.8	57.1	61.3	58.1
Tags	82.2	77.8	80.4	80.1
Remainder	54.5	49.5	52.4	52.1
Total First Half	61.9	53.3	54.3	56.5
Intact Second Half	62.0	53.2	54.3	56.5
Entire Fleece	61.9	53.3	54.3	56.5

Considering all three lots as a unit the combined shoulder, side, and back fleece sorts showed a shrinkage which corresponded closely withthat of the entire fleece (difference of 0.5 percent). Of the individual fleece sorts the side gave a shrinkage which most closely approached that of the entire fleece(difference of -1.5 percent). The two halves of the fleece had exactly the same shrinkage.

The proportionate amount of the different fleece sorts by weight for the three lots individually and combined are shown in table 22.

Table 22.- Percentage by Weight of Fleece Sorts to Half-Fleece, in all Breeds and Grades.

Fleece Sorts	Lot No.1	Lot No. 2	Lot No.3	All Lots
Shoulder	8.4	6.1	7.0	7.2
Side	20.0	30.0	18.6	22.9
Back	39.1	33.3	26.2	32.9
Belly	6.2	10.7	10.6	9.2
Tags	6.9	1.0	3.3	3.7
Remainder	19.4	18.9	34.3	24.2
Total	100.0	100.0	100.0	100.0

The shoulder made up a relatively small part of the half-fleece which was sorted. The back area was the largest of the fleece sorts, while the side and remainder are the next largest. The combined shoulder, side, and back sorts made up 62.9 percent of the fleece in all lots.

PROPORTIONS OF FLEECE SORTS IMPORTANT IN SAMPLING

The relation of the shoulder, side, and back sorts to the total for all three sorts gives information of value in determining the portion of wool to take from each of these sorts when taking a random sample from the tied fleece. The figures for the different lots and all lots are shown in table 23.

Table 23.- Percentage of Total by Weight of Fleece Sorts by Lots

Fleece Sort (Body Area)	Lot No.1	Lot No. 2	Lot No. 3	All Lots
Shoulder	12.5	8.8	13.4	11.6
Side	29.6	43.2	35.9	36.2
Back	57.9	48.0	50.7	52.2
Total	100.0	100.0	100.0	100.0

The random samples drawn from tied fleeces on the basis of these three lots should contain 52 percent of back wool, 36 percent of side wool, and 12 percent of shoulder wool. In the past the taking of samples has been based almost entirely on the judgment of the person who was sampling. Now we have some definite information on the proportions of each of these body sorts to include in order to have proper representation of each of the three sorts in a random sample. The first half of the fleece in all breeds amounted to 53.6 percent of the total by weight, while the second or intact half of the fleece amounted to 46.4 percent.

A Comparison of the Shrinkage of Side and Random Samples With the Shrinkage of the Entire Fleece.

The shrinkage of a side sample taken from the fleece before shearing was compared with the shrinkage of a random sample taken after the fleece had been tied and with the ultimate shrinkage of the entire fleece when it was scoured.

Table 24. Shrinkages of Samples and of Fleeces

Lot No.1

15 Fleeces from each Breed	Percent of Shrinkage				
Fleece Sample	Rambouillet	Targhee	Corriedale	Columbia	All Breeds 1/
Side	58.3	56.1	53.0	51.5	54.9
Random	57.7	57.4	53.9	53.4	55.8
Remainder	59.1	57.9	54.2	54.8	56.4
Entire Fleece	59.0	57.9	54.1	54.7	56.3
	Differences in Shrinkage Using the Entire Fleece as Base				
Side	-0.7	-1.8	-1.1	-3.2	-1.4
Random	-1.3	-0.5	-0.2	-1.3	-0.5
Remainder	+0.1	0.0	+0.1	+0.1	+0.1

1/ Weighted Average

The random samples in the case of all breeds were much closer than the side samples. (table 24) These tests indicate that the random samples gave better indications of the shrinkage of fleeces than did the side samples.

It is interesting to compare the size of the random and side samples in Lot No. 1.

Table 25. Percentages of Each Sample by Weight to the Entire Fleece in the Different Breeds

Lot No. 1.

15 Fleeces from each Breed					
Fleece Sample	Rambouillet	Targhee	Corriedale	Columbia	All Breeds 1/
Side	2.2	1.9	1.6	1.6	1.8
Random	3.1	2.7	2.1	2.0	2.4
Remainder	94.7	95.4	96.3	96.4	95.8
Entire Fleece	100.0	100.0	100.0	100.0	100.0

1/ Weighted Average

The random samples were slightly larger than the side samples. The average weights of the side samples for all breeds was 84 grams, while the random samples for all breeds on the average weighed 114 grams.

The results indicated that side and back samples were usually closer in shrinkage to the average for the entire fleece than samples from other body areas. The results further indicated that the shrinkage of a sample made up of shoulder, side, and back samples was closer to the shrinkage of the entire fleece than any single body-area sample, in the majority of cases. This was substantiated by the results obtained with side and random samples in which the random samples were closer in shrinkage to the shrinkage of the entire fleece than were the side samples. These random samples were taken from the tied fleeces, selecting wool from the shoulder, side, and back sorts.

Shrinkages of Side, Random and Blended Samples Compared with the Shrinkage of the Entire Fleece.

In connection with the shrinkage test of the side and random samples as compared with the shrinkage of the entire fleece, assupplementary test was made of small blended samples made up from the remainder of the fleece to see how accurately they indicated the shrinkage of the fleece. Three 400-gram blended samples were prepared from the remainder of the fleece after the side and random samples had been removed. These blended samples were made up by running the remainder of the fleece through the duster twice and making up the samples by repeated quartering.

This test gave an indication of the practicability and accuracy of obtaining samples of a fleece by using the duster so that all of the wool would not need to be scoured. This is particularly important in its application to preliminary results when fast and accurate results are required. Four Corriedale fleeces and three fleeces each from Columbia, Rambouillet, and Targhee sheep were used in the test of blended samples.

Table 26.- Shrinkages by Samples and Breeds

Based on Laboratory Weight of Grease Wool and 13% Moisture in Scoured Wool

	Shrinkages in Percent				
Breed / Sample	Rambouillet	Targhee	Corriedale	Columbia	All Breeds 1/
Side	57.6	60.7	58.0	53.0	57.3
Random	54.3	57.5	56.8	53.8	56.0
Blended					
No.1	58.3	59.3	58.2	54.7	57.5
No.2	58.4	58.9	57.6	54.5	57.1
No.3	58.3	59.2	57.6	54.6	57.2
All	58.3	59.1	57.8	54.6	57.3
Remainder	58.9	60.0	57.9	55.1	58.0
Entire Fleece	58.6	59.7	57.8	54.9	57.7

1/ Weighted Average.

Differences in Shrinkages Between Samples And Fleeces Using Entire Fleece as Base

Breed / Fleece Sample	Rambouillett	Targhee	Corriedale	Columbia	All Breeds
Side	-1.0	+1.0	+0.2	-1.9	-0.4
Random	-4.3	-2.2	-1.0	-0.9	-1.7
All Blended	-0.3	-0.8	+0.0	-0.3	-0.4
Remainder	+0.3	+0.3	+0.1	+0.2	+0.3

In this test, with 13 fleeces represented, the side sample was closer in shrinkage to the shrinkage of the entire fleece than were

the random samples. The main object of the test with these 13 fleeces was to find out whether representative 400-gram samples could be obtained from the remainder of the fleece by blending the wool through the duster twice and then selecting three 400-gram samples. The blended samples differed by less than 0.5 per cent in shrinkage from the entire fleece, and this result indicates that the small blended samples were very representative of the fleeces from which they were obtained. The remainder of the fleece, after the side and random samples had been removed, was very close in shrinkage to that of the entire fleece with all of the samples included. When the blended samples were compared directly with the "remainder" of the fleece from which they were taken, the difference in shrinkage amounted to around 0.7 percent.

A Comparison of Random and Commercial Samples and 5-Bag Lots

Shrinkage tests of samples and 5-bag lots were carried on in cooperation with the National Wool Marketing Corporation. Five of the Wyoming clips sampled in the field during the shearing season of 1937 were later located at the warehouse of the National Wool Marketing Corporation and arrangements were made for a cooperative test. Five-bag lots were selected outof the different clips according to commercial methods. The five bags were selected from 25 bags, which had been laid out by the National Wool Marketing Corporation. This selection was made on the basis of weight and correspondence of grade to the description given in the records of the corporation. The 25 bags from which each selection was made were not opened up, but the seams of the bags were opened. It was not possible to make a careful examination because the clips were stored in an unheated warehouse.

The 5-bag lots were taken to a scouring plant and sampled there. Samples were taken by two operators in two series. One series was taken according to the judgment of the operators and called the commercial samples, and the other series taken according to the usual mechanical method used in the field and called the random samples. The shrinkage information from the 5-bag lots scoured at the commercial scouring plant and the small samples taken at the plant and at the shearing shed are shown in Table 27.

Table 27.- Comparison of the Shrinkage of Random and Commercial Hand Samples with 5-Bag Lots. (Sample Bags).

5-Bag Lots Scoured at a Commercial Scouring Plant
Samples taken by Operators No.1 and 2 at Scouring Plant and Scoured at A.M.S. Laboratory
Shearing Shed Samples taken by Operator No. 1 and Scoured at A. M. S. Laboratory.
Shearing Shed Samples taken by Operator No. 2 and Scoured at Wyoming Laboratory

Samples and Operator	Clip No. 1	Clip No. 2	Clip No. 3	Clip No. 4	Clip No. 5
5-Bag Lots 1/	66.85	66.65	65.55	67.64	63.25
Scouring Plant Samples 2/					
Commercial -					
Operator No. 1	66.06	67.45	65.33	65.85	63.08
Operator No. 2	66.51	66.24	62.83	66.37	64.27
Both	66.28	66.86	64.02	66.10	63.65
Random					
Operator No.1	65.66	65.55	63.91	67.17	61.23
Operator No. 2	66.18	68.28	63.21	67.24	62.38
Both	65.96	67.09	63.54	67.21	61.87
All Scouring Plant Samples					
Operator No.1	65.85	66.55	64.54	66.49	62.06
Operator No.2	66.31	67.36	63.04	66.87	63.10
Both	66.10	66.98	63.75	66.70	62.61
All Shearing Shed Samples at Wyoming 3/		4/	5/		
Operator No.1	65.59	70.93	65.84	66.76	62.02
Operator No.2	65.98	69.37	63.01	64.71	58.96
Both	65.73	70.37	65.06	66.03	60.93

1/ Shrinkage of 5-bag lots based on billed weights of grease wool and conditioned weight of scoured wool.

2/ Shrinkage of all scouring-plant samples based on conditioned weights, both grease and scoured wool.

3/ Shrinkage of all shearing-shed samples at Wyoming taken by Operator No. 2 based on shearing-shed weight in grease and natural atmospheric conditions for scoured wool.

4/ Samples taken from a straight "Fine" band "Chute cut" for fine grade in autumn.

5/ Weighted averages for three different bands which awere sampled at shearing shed.

Shrinkage of all shearing-shed samples taken by Operator No.1 based

on sorting weight in grease and conditioned weight for scoured wool.

The shrinkage of four out of the five groups of samples taken at the plant were within 1 percent of the shrinkage of the entire 5-bag lot. All of the group of samples except one shrank slightly less than the entire 5-bag lot. The commercial samples showed slightly less variation from the entire 5-bag lot than the random samples.

Comparison of Shrinkage of Small Samples With Shrinkage of Sublots and Entire Lots

A sublot, consisting of approximately 10 bags spaced at equal numerical intervals throughout the lot, was laid aside. The bags of the sublot were opened and each of the fleeces was placed in its proper grade pile. Samples (handfuls) of wool were then taken from each fleece, wool being selected from the major body sorts (shoulder, side, and back) which make up approximately 95 percent of the fleeces by weight. In the case of graded lots it was not necessary to make up the different grade piles, and the fleeces were sampled as they were removed from the bags.

Three different lots were tested (Wyoming Original Bag, Montana Graded 1/2 Blood, Idaho Graded 1/2 Blood). Table 28 shows the structure of these lots, sublots, and the samples made up from them:

Table 28.- The Number of Bags in the Entire Lot and the Number of Bags and Samples in the Sublot

Lot	Entire Lot	Sublot	
	No. Bags	No. Bags	No. Samples
Wyoming Original Bag	82	9	6
Montana Graded 1/2 Blood	126	10	24
Idaho Graded 1/2 Blood	258	10	12

The number of samples varied because after the first lot was run additional samples were run in the second lot to test repeated sampling by two operators. In the third lot, duplicate samples were taken by one operator. The samples were taken from the tied fleeces, and then the fleeces were untied and sorted. The mill used only the main body sorts which amounted to 95 to 96 percent of the total by weight. The offsorts including tags were not scoured.

In one lot, a corrected yield was calculated for the entire unsorted fleece by obtaining the shrinkage of a sample of tags and correcting for the weight of the tag sort.

The sampling method used has always aimed to obtain representative samples from the shoulder, side, and back. Wool samples taken from these body areas are directly comparable with the processed mill lots which consisted of the major sorts.

LABORATORY METHOD OF SCOURING

The scouring procedure consisted of passing the samples through a wool duster and then floating them through a semi-commercial scouring plant made up of 6 bowls measuring 10 feet long, 18 inches wide and 18 inches deep. The formulas used in the solutions for the first 3 bowls were made up as follows:

Percent by Weight	First Bowl	Second Bowl	Third Bowl
Soap	1/10	1/2	1/4
Soda	1/4	1/10	1/10

The last three bowls contained rinse water. The wool was divided into portions of approximately 2,000 grams and floated through the scouring liquor by hand and fed through the squeeze rolls between each bowl. Each bowl was equipped with a perforated movable tray that could be raised out of the solution. The bits of wool that sank in the solution were recovered before they dropped to the bottom of the bowl. The temperature of the baths in the different bowls was kept at 120 degrees F. When the wool came out of the last squeeze roll, it was conveyed through a commercial drier at a temperature of 130-140 degrees F. The scoured wool was then placed in containers and left to stand overnight, so that the moisture present in the wool would be equally distributed throughout all of the wool. Then it was run through a wool duster and weighed. Subsamples were taken from each sample in proportion to the quantity of scoured wool in the sample. These subsamples were dried to a constant weight in a conditioning oven. All final scoured weights were corrected to a basis of 12 percent of moisture. Tests were made on the cleanliness of the scoured wool by means of soxhlet and alcohol extractions, and ashing on a number of samples (A.S.T.M. Designation D252-36).

The scouring of the large lots of wool at the mill was carried on by the usual commercial procedure and checks were made on the cleanliness of the scoured wool. The yield of the lots was reported as the yield of top, noils, slubbing, and card waste. This yield includes practically all of the scoured wool.

Table 29.- Comparison of the Shrinkage of Samples, Sublots, and Entire Lots.

Shrinkages of Samples Based on Yield of Scoured Wool Containing 12% Moisture.
Shrinkages of Mill Lots Based on Yield of Top, Noil, Slubbing, and Waste Containing 12% Moisture

Lot	All Samples		Sub-lot	Entire lot
	Mean	Stand. Dev.		
Wyoming Original Bag	56.4	1.887	57.0	56.8
Montana Graded 1/2 Blood	59.7	0.980	60.4	58.5
Idaho Graded 1/2 Blood	55.6	0.594	54.6	53.4

Difference in Shrinkage, Using the Entire Lot as a Base

	Sublot	All Samples
Wyoming Original Bag	+ 0.2	-0.4
Montana Graded 1/2 Blood	+ 1.9	+ 1.2
Idaho Graded 1/2 Blood	+ 1.2	+ 2.2

The samples showed shrinkages within 2.2 percent of the entire lot, and in most cases the shrinkages of the samples were higher than that of the entire lots. The variation of the different samples, as indicated by the standard deviation was greatest in the Wyoming lot with 6 samples; intermediate in the Montana lot with 24 samples; and smallest in the Idaho lot with 12 samples. These differences in shrinkage between the samples and the entire lot show not only the error in sampling the sublot, but also the error in selecting the sublot from the entire lot.

It is interesting to compare the shrinkages of the samples taken from each sublot against the sublot. In this case the differences are as shown in table 30.

Table 30.- Differences in Shrinkage between Samples and Sublot. Samples Taken from Sublot. Sublot Used as Base

Wyoming Original Bag	-0.6
Montana Graded 1/2 Blood	-0.7
Idaho Graded 1/2 Blood	+ 1.0

The correspondence of the samples and the sublots from which the samples were taken is very close. It gives encouragement to the program of finding a sampling method that will give representative shrinkages and grades from a larger lot. However, it also points out that, in order to obtain such results, the tags must be removed which is further confirmed by the results obtained in comparing composite bags and samples taken from them.

There is still the problem of obtaining a sublot (approximately 10-bag lot) which will represent the larger lot. In this study the differences in the shrinkages of the sublot and the entire lot were all under 2 percent. In all cases the sublots had higher shrinkages than the entire lots.

The figure of 2 percent in difference between samples has been set up as an acceptable difference insofar as practical information to the wool grower is concerned.

The close correspondence of the shrinkage results between small samples and large lots of wool, in the three large lots tested to date, is very encouraging and gives substantial support to the program of obtaining representative samples of wool from a clip or large lot of wool.

In the mill work only the major sorts were processed, therefore to be applicable to field work in which the entire fleece has been the unit, some allowance would need to be made for tags and the small quantity of neck and britch wool that was removed when the wool was sorted at the mill. As mentioned before, the sampling method has been predicated on the basis of taking handfuls of wool from the shoulder, side, and back areas of the tied fleece, which make up the major part of the fleece.

In the mill tests of shrinkage, the entire lot consisted of the major body sorts with the tags, neck and britch wool removed. The samples were taken before the wool was sorted but did not contain any tags, neck or britch wool and hence were directly comparable with the entire lot as it was processed at the mill. In one lot of wool tested at the mill a sample of tags was taken and the shrinkage of the lot was corrected to allow for the tags. The inclusion of the tags increased the shrinkage of the lot by 0.6 percent.

Another basis for the comparison of the sublots and the entire lots was in the percentage by weight of the different grades in the original bag lot of Wyoming wool.

Table 31.- Percentage of Grades by Weight in Entire Lot and Sublot . 91 Bags of Original-Bag Wyoming Wool

Grade	Entire Lot 82 Bags	Sublot 9 Bags
Fine	25.85	16.14
1/2 Blood	66.89	75.58
3/8 Blood	6.77	7.77
Gray	0.49	0.51
Total	100.00	100.00

There was around a 9 percent difference in the Fine and 1/2 Blood grades between the entire lot and the sublot. The sublot, as an indicator of the entire lot, had 9 percent less of the Fine grade and 9 percent more of the 1/2 Blood grade. Thus, it was difficult to pick out representative bags from a lot unless the shearing-shed information was known. This was strikingly shown in some grading work carried on at the shearing shed during the 1938 shearing season, in which the first bags shorn from each band contained considerably more medium to coarse wool and less fine wool than the last bag shorn from each band. The information from this clip is shown in table 32.

Table 32.- Percentage of Grades by Weight

Grade	First Bag in Band	Last Bag in Band
Fine	38.8	67.0
1/2 Blood	42.2	22.1
3/8 Blood	16.8	10.2
1/4 Blood	2.2	0.7
Total	100.0	100.0

All of the entire lots were sorted before they were processed at the mill, and the sorting reports give an interesting comparison between the percentage of the different sorts present in the sublots as compared with the entire lots.

Table 33.- Percentage by Weight of the Different Sorts

Sorts	Wyoming Original Bag		Montana 1/2 Blood		Idaho 1/2 Blood	
	Entire Lot	Sublot	Entire Lot	Sublot	Entire Lot	Sublot
AB	26.70	17.17	11.17	13.51	5.38	6.79
B	66.87	70.92	76.88	71.69	72.04	68.01
CD	3.81	8.44	8.45	10.57	18.85	21.09
E/EE	0.22	0.47	0.10	- -	0.28	0.10
AB Burry	- -	- -	- -	- -	- -	0.21
E Burry	- -	- -	0.51	0.55	0.43	- -
Burry	0.30	0.28	- -	- -	- -	- -
B Black	- -	- -	0.03	0.28	0.05	- -
AB Black	- -	- -	- -	- -	- -	0.10
Paint Clips	0.22	0.28	0.48	0.46	0.78	0.72
Stained	1.81	2.25	2.38	2.85	2.19	2.98
Tags	- -	- -	0.10	0.09	- -	- -
Gray	0.07	0.19	- -	- -	- -	- -
Total	100.00	100.00	100.00	100.00	100.00	100.00
Paper Strings	0.5	0.5	0.5	0.9	0.4	0.6

Differences in Percentage by Weight of Different Sorts
Deviation of Sublot, Using Entire Lot as a Base

Sorts	Wyoming Original Bag	Montana 1/2 Blood	Idaho 1/2 Blood
AB	-9.53	+2.34	+1.41
B	+4.05	-5.19	-4.03
CD	+4.63	+2.12	+2.24
EE	+0.35	-0.10	-0.18
AB Burry	- -	- -	+0.21
B Burry	- -	+0.04	-0.43
Burry	-0.02	- -	- -
B Black	- -	+0.25	-0.05
AB Black	- -	- -	+0.10
Paint Clips	+ 0.06	-0.02	+0.06
Stained	+ 0.44	+0.57	- -
Gray	+ 0.12	- -	- -
Tags	- -	- .01	- -

In the first lot of original bag wool from Wyoming, there was a considerable difference in the sorting between the sublot and the entire lot as the sublot did not have as much fine wool in it as the entire lot by around 9 percent. As would be expected, the differences in sorting between the sublot and entire lot were very small in the graded lots of Montana and Idaho 1/2 Blood. The more uniform the original lot was, the easier it was to obtain a representative series of bags in the sublot to represent the entire lot. The sublots in all cases contained slightly more of the coarser sorts than the entire lot.

SUMMARY OF RESULTS

(1) Samples drawn at random from the shoulder, side, and back areas of fleeces in the composite bags were, on the average, around three percent less in shrinkage than was the entire bag.

(2) Shrinkages of the composite bags were lowered by 1 3/4 percent when the tag sort was removed and allowances were made for the samples removed and the string used in tying the fleeces.

(3) Grade-pile samples gave shrinkages 1.4 percent higher than the samples from the composite bag made up from these grade piles.

(4) Every 10th bag selected throughout a clip gave a good representation of the clip as indicated by the proportion by weight of the different grades.

(5) Composite bags made up by selecting fleeces at spaced intervals of time during the shearing of a clip did not give as good representation of the clip as 10 bags spaced throughout the clip.

(6) The first bag sacked from a band of sheep was coarser in grade than the last bag sacked from a band, provided the sheep were of similar ages, and all grades from Fine to 1/4 Blood are represented in the clip.

(7) Selection of fleeces at equally spaced intervals through a clip to make up 10 bags of wool gave the most representative picture of the clip as indicated by the percentage by weight of the different grades. However, this method of fleece selection gave results that were only slightly more representative than the 10 bags selected at equal intervals throughout the clip.

(8) Side and back fleece sorts gave shrinkages that were most representative of the entire fleece. A combination of the shoulder, side, and back fleece sorts gave results very close to the shrinkage of the entire fleece.

(9) Sorted and unsorted halves of the fleece gave similar shrinkages, indicating that the two halves of the fleeces were similar in shrinkage.

(10) Shrinkage of random samples taken from the shoulder, side, and back portions of tied fleeces were closer to the shrinkage of the entire fleece than was the shrinkage of side samples taken from the same fleeces before they were tied.

(11) A series of blended samples, weighing 400 grams each, gave shrinkages very close to the shrinkage of the remainder of the fleece from which they were taken. The remainder of the fleece contained all of the fleece except the small side and random samples.

(12) The average shrinkage of a series of samples taken at the warehouse from 5-bag test lots was within 1 percent of the shrinkage of the entire 5-bag lots in four cases out of the five clips from which 5-bag test lots were selected.

(13) The average shrinkage of a series of small samples taken from the sublots scoured at the mill showed shrinkages within 2.2 percent of the shrinkage of the entire lot scoured at the mill, and in most cases the average shrinkages of the samples were higher than those of the entire lots.

(14) The series of small samples taken from the sublot showed an average shrinkage within 1 percent of the shrinkage of the sublot when it was scoured at the mill.

(15) The sublot did not represent the entire lot in respect to shrinkage as closely as the small samples represented the sublot.

(16) The quantity of fine and half blood grades in the sublot and the entire lot differed by around 9 percent in each of the grades.

(17) The sorting reports showed the same differences between the sublot and entire lot in respect to percent of sorts by weight as was shown in the grading reports.

(18) In three different clips, every fleece of which was graded in the order in which it was sheared, it was found that it did not make much difference (in obtaining representative proportions of the different grades in the clip) whether every 10th bag was selected or whether 10 bags are selected, spaced at equal intervals through the clip.

(19) In this same study of three different clips it was found that the first bag from each band was consistently coarser in grade than the last bag shorn from each band if the sheep were all of equal age.

(20) The grease content of the scoured wool in the tests of samples, sublots, and entire lots varied from 0.32 to 0.93 percent.

(21) In a series of samples taken from the sublots by two different operators there was no significant difference in shrinkage between the first and last of the four samples taken by each operator. Neither was there significant difference in average shrinkage between the samples taken by each operator.

(22) For the first time we now have definite checks of the shrinkage of a series of small samples as compared with the shrinkage of the entire lot from which they were taken, when the entire lot was processed at the mill.

(23) The differences between the average shrinkage of the series of small samples and of the entire lot were all within 2 percent. In the past, when furnishing shrinkage information to wool growers, this 2 percent difference in shrinkage has been used as a practical limit of variation between duplicate samples from the same band of sheep.

(24) A system of orderly spacing in the selection of sample fleeces or bags of wool out of a large lot of wool has been more satisfactory in obtaining a representative sample of a lot than a random selection.

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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service

PROGRESS IN WOOL SHRINKAGE RESEARCH DURING YEAR 1939

By Warner M. Buck
Specialist in Marketing Wool

Washington, D. C.
June 1940

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INTRODUCTION

Wool in the condition it is shorn from the sheep is known as "grease wool" and contains varying amounts of extraneous substances most of which have no commercial value. These substances are in the form of grease, dried perspiration, sand, vegetable matter, etc. The loss in weight that occurs when the wool is scoured is termed "shrinkage." The shrinkage of wool is influenced primarily by the breed of the sheep producing the fleeces, the area in which they range, the nature of their feed and other factors. Wools of the United States differ greatly in shrinkage. It is estimated that extraneous and indigenous substances present in domestic wool range from about 35 percent to about 75 percent of the weight of the shorn fleece.

The Agricultural Marketing Service, in response to insistent demand from producers, has undertaken to develop a quick and reliable method of sampling and testing wool for shrinkage. The method being sought must be practical as well as reliable and therefore should be acceptable to all branches of the industry as a "standard method." That the accomplishment of the objective is difficult is recognized by the Service. Problems not easily solved are presented by the numerous variables in the constituent elements of shrinkage and by the lack of uniformity in the preparation of the clip for market.

Although some shrinkage studies were conducted by the Department of Agriculture in the past, the present investigations under this project were instituted in 1937. Work has since been done in the States of Montana, Idaho, Wyoming, Utah, Texas, and Colorado, and in the manufacturing centers of the East. Various methods of sampling have been tried and the results of each studied. In order to insure the greatest possible degree of accuracy, scouring equipment designed for handling small quantities of wool, but built to conform with commercial machines, has been installed in the laboratory of this Service.

In the course of these investigations, reports of the shrinkages of samples are made public from time to time. In making this information available to cooperators, the Service makes clear its inability definitely to correlate the shrinkages of the samples with that of the lot or clip from which the samples were selected. When this can be done the objective will be attained, but considerable work of a fact-finding nature lies ahead before this goal can be reached.

EFFECT OF SHRINKAGE ON WOOL PRICES

The shrinkage factor influences the value of "grease wool" more than any other, as the waste material must be removed before the wool can enter the manufacturing processes. The following is an illustration of the extent to which the contained foreign matter alone will affect the value of grease wool. If wool is worth 85 cents per pound, scoured basis, and its shrinkage is 58 percent, its grease value would be 35 3/4 cents, on the other hand if its shrinkage were 70 percent its grease value would be only 25 1/2 cents per pound. When Fine wool produced in the United States, which often sells at 85 to 90 cents a pound clean basis, varies in shrinkage from possibly 57 percent to as much as 75 percent, depending upon a number of factors, the importance of having reliable shrinkage information simply cannot be minimized.

SHRINKAGE CUSTOMARILY ESTIMATED

It is the custom for the wool buyer, when purchasing grease wool, to estimate the probable yield of the scoured product and base his price on this estimate. It is said that experienced wool buyers, as a result of intensive training, are able merely by inspecting the fleeces to estimate the actual shrinkage of a clip of wool within 1 percent or 2 percent. However, it seems there is no authentic information available to substantiate this claim, nor are there any means of determining just when or under what conditions this degree of efficiency is attained. A few expert buyers possibly do come very close in their estimates, however, although this may be true on the average it might not apply to individual clips or lots. In other words they may be too high on some clips, and too low on others so that the underestimates will to a considerable degree offset the higher ones. Although this may be satisfactory to the buyers of wool, there have been many protests from the producers and their organizations when in their opinion shrinkages have been overestimated.

At the present time, practically the entire domestic clip is marketed and manufactured without any information being obtained by either the growers or marketers of wool regarding the shrinkage of individual clips. This is primarily because of the fact that the identity of individual clips is lost either when the clips are commingled in grading in the warehouses or in the blending which is done in the manufacturing processes. Although tests are made on some individual lots such a practice is not usual. It is therefore extremely difficult, if not impossible, for wool growers to obtain information regarding the grade and shrinkage of their clips, based on actual tests. Information of this nature that is available remains in the possession of those who buy the wool. The producers are fully aware of these conditions and are urging that test methods be established whereby they can obtain reliable grade and shrinkage information quickly.

DEVELOPMENT OF SHRINKAGE TEST METHODS UNDERTAKEN

It is often stated in the wool industry that the shrinkage of wool is quite indefinite as no two mills will obtain the same yield even for portions of the same lot of wool. It is reasonable to assume that in instances of this kind either one or two things have happened. One manufacturer did not clean his wool as thoroughly as did the other or there was some difference in the wool itself. From the standpoint of producers the question of whether a manufacturer scours his wool hard or light is immaterial, as their interest is entirely in determining a fair basis of evaluation. This basis is the amount of clean dry fiber in grease wool.

The potential benefits of having available a means of appraising the shrinkage of wool other than that of estimating, have prompted many efforts to develop methods less empirical. At the present time investigators in several agricultural experiment stations, technical organizations, and Government agencies are working individually or cooperatively on various phases of the problem. To merit acceptance, a method must not be too time-consuming, must be economically and commercially feasible, and by all means must be capable of being repeated.

BASIC DATA SOUGHT IN AMS LABORATORY

In order that basic data regarding wool shrinkage might be obtained, numerous experiments have been conducted in the laboratory of the A.M.S. Studies of the effect of different scouring solutions, of washing with various ratios of scouring liquor to wool, of the number of dustings and of the moisture content of both grease and scoured wool are all phases of these investigations which have received the attention of the technical personnel.

To insure a fixed basis for computing results of tests in our work, it was necessary to have the scoured wool from all samples on definite bases of moisture and impurities. Based on experiments on wool cleansed in our laboratory and on commercially cleansed wool, the following standard has been tentatively adopted by us.

1. Scoured wool shall not contain more than 1.0 percent petroleum ether extract or grease.

2. Scoured wool shall not contain more than 1.0 percent alcohol extract, after the grease has been extracted with petroleum ether.

3. Scoured wool shall not contain more than 1.0 percent ash.

4. The standard moisture content for scoured wool shall be 12 percent.[1/] All shrinkages shall be determined on the basis of scoured wool weights as calculated at 12 percent moisture content.

1/ The use of a standard moisture content of 12 percent was decided upon after some of the studies, described in this report, had been completed on the basis of scoured weights calculated at 13 percent moisture.

STUDY OF MULTIPLE RINSE PROCEDURE

Commercial wool-scouring trains are generally made up of five scouring bowls. Customarily the bulk of the cleansing is done in the first bowl where about 85 percent of the original impurities are removed. Considerable cleansing is brought about in the second bowl where an additional 10 percent to 13 percent of the original amount of impurities is eliminated. In the third bowl the cleansing is completed with the removal of 1 percent to 4 percent of the original impurities. Following this treatment the wool contains possibly 1 percent to 2 percent of impurities. In the fourth bowl some of the residual soap and alkali are rinsed out and at times the wool is blued to impart a whiter color. The fifth bowl is used for further whitening operations, the wool being treated with dilute sulfuric acid and often hydrogen peroxide. The presence of sulfuric acid in the fifth bowl at once precipitates and fixes on the wool such impurities as the wool has carried into this bowl. Thus no grease or soap is removed in this bowl, although absorbed alkali is neutralized by the acid solution. Six-bowl trains are seldom used commercially for scouring alone. When employed the operations will usually include both scouring and carbonizing, the sixth bowl being used for the carbonizing acid. It is thus seen that, commercially, scouring is done in the first three bowls, rinsing in the fourth, with the fifth and sixth bowls being used for bleaching and application of a carbonizing acid.

The scouring train in the laboratory of this Service is made up of six bowls. It had been the practice to scour in the first three bowls, using the last three for rinsing. However, qualitative observations of the rinse in the fifth and sixth bowls showed that no grease or soap was being removed from the wool in these bowls since the water remained clear. The only component that might have been rinsed off in these bowls was the alkali on the wool which could have been rinsed off and still have left the solution clear. In the light of these observations it appeared desirable to determine just how much alkali was being removed from the wool in three rinses as compared with that removed in one rinse, and to decide whether three rinses were actually necessary.

Approximately 3,000 grams of 3/8 blood were divided into two portions. One portion was scoured, given one rinse, and dried. The other portion was scoured, given three rinses, and dried. There was no difference in color between the two portions. The wool that had been given three rinses was slightly more felted than the sample that had received only one rinse. The samples were tested for absorbed alkali by the following method. Five grams of the sample were stirred thoroughly with 200 milliliters of 2 percent boric acid solution. The solution was pressed out of the wool and the extracted alkali was titrated with standard sulfuric acid using methyl orange as an indicator.

The results follow:

Sample	Percent of alkali calculated as soda ash
1 rinse	0.25
1 rinse	0.36
1 rinse	0.28
1 rinse	0.27
1 rinse, Average	0.29
3 rinses	0.25
3 rinses	0.28
3 rinses	0.25
3 rinses	0.28
3 rinses	0.29
3 rinses, Average	0.27

Another sample was given one rinse in the fourth bowl at the end of a day of scouring when the water in the fourth bowl was very cloudy from rinsing other samples. This wool was also tested for alkali with the following results:

Sample	Percent of alkali
1 rinse in cloudy water	0.27
1 rinse " " "	0.22
1 rinse " " "	0.26
Average	0.25

Apparently then, wool given one rinse shows practically the same amount of absorbed alkali as wool given three rinses. Since wool given one rinse is less felted and since the wool given one rinse requires passage through only four bowls instead of six, it appears logical to give our scoured wool only one rinse. This change has now been put into effect.

DUSTING OF SCOURED WOOL

In laboratories engaged in testing wool samples for shrinkage determination the scoured wool is subjected to a mechanical treatment in order to remove sand and dust that remains even after a thorough washing. In order to determine at just what point the wool has been treated sufficiently to remove extraneous matter without incurring fiber loss, specimens were subjected to numerous dustings. As a result of successive dustings it was found that the scoured wool incurred the following average losses:

Table 1. - Loss in dusting

Number of dustings	Loss	Shrinkage	Difference	Corrected shrinkage
	Percent	Percent	Percent	Percent
No dusting	0.0	55.00		55.00
			0.90	
1st "	2.0	55.90		55.77
			0.45	
2nd "	1.0	56.35		56.09
			0.31	
3rd "	0.7	56.66		56.26
			0.14	
4th "	0.3	56.80		56.27
			0.13	
5th "	0.3	56.93		56.27
			0.14	
6th "	0.3	57.07		56.27
			0.13	
7th "	0.3	57.20		56.27

Analyses of the accumulation of dust from the first two dustings of a large amount of scoured wool gave the following results:

	Percent
Ash	26.2
Vegetable material	47.5
Wool and other substances (by difference)	26.3
Total	100.0

The loss of this material would appear to be of benefit to the wool, especially since the small amounts of wool present in the dust are so short in length as to be of no commercial value.

It will be noted that after three dustings the sample loses approximately 0.3 percent of its weight during each dusting, or in terms of shrinkage, gains approximately 0.13 percent. It appears probable that these small differences are due to actual loss of wool fiber during the dusting. The large losses during the first three dustings, however, are mainly actual dust, sand, and vegetable matter, and it would appear desirable to purify the wool of these materials by dusting. It will be noted that if a correction of 0.13 percent to 0.14 percent for the amount of wool lost is subtracted from the shrinkage after each dusting, the shrinkage attains a nearly constant value after two dustings. We have, therefore, tentatively adopted the practice of running the scoured wool through the duster twice.

Similar analyses are planned for dust removed from scoured wool that has already been dusted one or more times. Thus a sample of scoured wool would be dusted as many as seven or eight times and the dust removed at each operation would be collected and analyzed separately.

INFLUENCE OF VARIOUS SCOURING SOLUTIONS

An experiment was undertaken to determine whether the use of different scouring solutions might result in different shrinkages. Information on this question appeared necessary since the shrinkages of our samples are at times compared with bulk shrinkages obtained by manufacturers and commission scourers. As a rule commission scourers use more sodium carbonate in their scouring liquors than has been our practice. Moreover, if different scouring solutions give appreciably different shrinkages, it would be essential to standardize the scouring solutions used by laboratories cooperating in shrinkage work.

Fifteen Rambouillet fleeces were used in this study. In order that each fleece might be made into a homogeneous mass it was thoroughly dusted and blended. From each blended fleece 21 samples, each weighing 100 grams, were drawn. Fifteen of these 100-gram samples were grouped together in order to make a composite sample. In this manner 21 composite samples, each containing 1500 grams of dusted wool, were made up. These composite samples were scoured in different solutions and the shrinkages calculated according to our standard laboratory method. The scouring effect of each solution was established by determining the shrinkages of three identical samples put through the solution.

The results of this test are shown in table 2.

Table 2. - Shrinkages of blended samples as scoured with different solutions

Scouring solutions				Shrinkages of Samples 1/	
	Bowl	Soda Ash	Soap	Individual	Average
		Percent	Percent	Percent	Percent
Regular A Solution	1	0.25	0.10	58.2	
	2	0.10	0.50	58.4	
	3	0.10	0.25	58.4	58.3
B	1	0.10	0.10	58.3	
	2	0.10	0.10	58.4	
	3	0.10	0.10	58.5	58.4
C	1	0.30	0.05	58.2	
	2	0.30	0.05	58.2	
	3	0.30	0.05	58.4	58.3
ASTM D Tentative Standard	1	0.30	0.10	58.2	
	2	0.30	0.10	58.1	
	3	0.30	0.10	58.2	58.2
E	1	1.00	-	57.4	
	2	1.00	-	57.0	
	3	1.00	-	57.0	57.1
F	1	1.00	0.05	58.4	
	2	1.00	0.05	58.1	
	3	1.00	0.05	58.0	58.2
G	1	1.00	0.10	58.0	
	2	1.00	0.10	58.1	
	3	1.00	0.10	57.9	58.0

1/ 13 percent moisture in scoured wool.

Qualitative examination of the scoured samples showed sample A to be whitest and best in appearance although it was only slightly superior to samples B, C, and D. Sample E was definitely poor in color, and the poor scouring in this case is reflected by the lower shrinkage of the sample. Samples F and G were good, but slightly poorer than B, C, and D.

In table 2 the shrinkage of any properly scoured sample can be expressed as 58.2 percent ± 0.3 percent, the ± 0.3 percent being a measure of the variability of the sample itself, rather than of the effect of the scouring solution upon its shrinkage. It will be seen that the only scouring solution not giving shrinkages within these limits is E, which is composed of 1 percent soda ash with no soap. It can be concluded that if a scouring solution is fresh and contains a minimum of 0.1 percent soda ash and 0.1 percent soap, the wool put through in the usual manner will be properly scoured and will have just as high a shrinkage as if larger quantities of scouring materials had been used.

Although the quantitative shrinkage results of this test indicate that our regular scouring solution is as efficient as any other scouring solution tried, and the qualitative statements as to appearance indicate that our regular scouring solution is better than the other solutions, there are other factors that will necessitate changing our regular scouring solution. The introduction of pumps, duckers, rakes, and crabs for mechanically handling the scouring of the wool will have a tendency to cause foam. The difficulty from foam with the regular scouring solution while the machinery is running will be insuperable. For this reason it is believed it will be necessary to use a scouring solution containing less soap. Soap concentration greater than 0.05 percent acquires a troublesome foaming tendency.

In deciding upon a standard scouring solution that will function properly in our scouring equipment with the added mechanical features, it is of interest to note that the American Society for Testing Materials has a tentative standard for all three bowls of 0.30 percent of sodium carbonate and 0.10 percent soap. The results obtained in our tests on different scouring solutions indicate that these amounts of materials could be reduced and still give effective scouring. As a definite suggestion of a standard scouring solution that will work well in our bowls when completely mechanically equipped, and that has been shown to yield a well-scoured wool with a shrinkage in uniformity with that obtained from the use of other accepted standard scouring solutions, a solution of 0.30 percent sodium carbonate and 0.05 percent soap is proposed.

DETERMINATION OF SUITABLE METHODS FOR SCOURING SMALL SAMPLES

The equipment in the wool laboratory appears wholly suitable for scouring samples weighing 10 to 20 pounds or more. However, the passing of small samples of 1/4 pound up to 2 pounds through the open tubs, and recovery of all wool belonging to these small samples involves more labor than is justified by the amount of wool involved. The possibility of placing the wool in small wire baskets and cleansing the wool by immersing the basket in the successive scouring liquors, with appropriate agitation of the wool, appears logical as far as the saving in time and labor is concerned. However, the effects of such a procedure on the shrinkage of a sample should first be investigated.

In approaching the problem of determining the best method of scouring a small sample in a basket, several factors at once suggest themselves. First, how large may a sample be in a basket and be properly cleansed. Second, through how many baths should a sample be put in order to be properly cleansed. Third, would it be necessary to put a sample through a pair of squeeze rolls after each scouring bath, or could the number of squeezes be reduced and proper cleansing still be maintained?

To obtain information to answer the above questions, 6000 grams of grease wool were dusted and blended until homogeneous, and eight small samples made up from the blended wool. These samples were scoured in various ways and the shrinkage of the individual samples then determined. The samples were also tested for grease and ash.

A comparison of the results obtained in this test is shown in table 3.

Table 3. - Shrinkages of samples tested under various conditions

Sample	Open tub or basket	Grams of wool per basket	Number of Scouring bowls	Number of Squeeze rolls	Shrinkages 1/ of samples: Individual	Shrinkages 1/ of samples: Average	Ash	Grease
					Percent	Percent	Percent	Percent
A	Open tub	0	3	3	53.0	53.1		
B	Open tub	0	3	3	53.2		0.80	0.34
C	Basket	100	3	3	51.9	51.9	0.83	0.37
D	Basket	300	3	3	52.3	52.3	0.77	0.42
E	Basket	600	3	3	51.9	51.9	0.80	0.45
F	Basket	300	3	1	51.5	51.5	0.89	1.48
G	Open tub	0	2	2	52.8			
H	Open tub	0	2	2	53.0	52.9	0.80	0.50

1/ 12 percent moisture in scoured wool.

A study of the above table reveals that -

1. Samples A and B scoured in three open tubs have the highest shrinkages and the lowest amount of grease of any of the samples.

2. Samples scoured in baskets are significantly lower in shrinkage than those scoured in open tubs.

3. The more wool scoured in a basket at one time the more grease will be left in the sample; hence, the shrinkage of the sample will tend to be lower.

4. The percentage of grease found in the samples is in consistent agreement with what one would expect from the different scourings, although there are small variations in shrinkage from what one would expect.

5. The percentage of ash appears to bear little relation to the method of scouring or to the shrinkages of the samples.

The most important point brought out by these tests is that samples scoured in baskets are significantly lower in shrinkage than samples scoured in tubs. By means of grease extraction tests on the samples it has been clearly shown that the samples scoured in baskets are not as well scoured as those in the open tubs, therefore, it appears that at least part of the difference is due to the presence of a larger amount of impurities in the basket-scoured samples. On the other hand, if all the samples are corrected to the same grease and moisture content in the scoured wool, the open-tub scoured samples are still significantly higher in shrinkage.

Two explanations at present might possibly account for the difference in shrinkages between samples scoured in baskets and those scoured in open tubs. One would be that there has been a loss of wool from the open-tub scoured samples sufficient to make the shrinkages of the samples high by 1.0 to 1.2 percent. This is possible and yet appears very improbable because tests have been run in the past on the amounts of wool fiber lost through our screen in the open bowls, and this loss has never amounted to more than 0.2 percent shrinkage and is generally below 0.1 percent shrinkage. The other explanation would be that the grease extractions represent an artificial and arbitrary fraction of the total impurities and this arbitrary fraction has only a partial correlation with the total amount of impurities present and hence with the shrinkage of the samples.

As a tentative conclusion it appears that open-tub scouring is more reliable. However, it appears desirable to repeat these scourings, paying particular attention to recovering the wool that is lost beneath our screens, and attempting to develop an analytical method for impurities which would have a better correlation with the differences in shrinkage. This question is of importance to all laboratories engaged in wool shrinkage investigations.

STUDY OF MODIFICATIONS OF THE RANDOM SAMPLING METHOD

Tests were conducted on 15 Rambouillet fleeces to determine possible modifications of the random sampling methods. The procedure followed was to weigh each fleece and then to sample it according to the usual random method, that is to pull small handfuls of wool from the different parts of the fleeces, taking approximately 1/4 pound from each. After this customary random sample had been selected a second sample was taken in exactly the same manner, except in this case the sample was approximately three times as large. The weights of the second samples were approximately 3/4 pound each. Additional random samples were also taken by pulling handfuls of wool both from the exterior of the fleece and from deep within the interior. All samples were tested separately and the shrinkages compared with the shrinkages of the entire fleece from which they were taken.

The results of this test are shown in table 4.

Table 4. - Variability and probable errors of various random sampling methods

Fleece number	Percent of Shrinkage 1/				Differences 2/			Squares of Diff.		
	Fleece	Random	Large Ext.&Int. Random		Random	Large Exterior and Int.		Random	Large random	Ext.& Int.
	Percent	Percent	Pct.	Percent	Percent	Percent	Percent			
16	61.2	58.9	61.1	59.6	- 2.3	- 0.1	- 1.6	5.29	0.01	2.56
17	56.2	57.4	56.9	57.0	+ 1.2	+ 0.7	+ 0.8	1.44	0.49	0.64
18	54.0	59.9	49.1	50.6	+ 5.9	- 4.9	- 3.4	34.81	24.01	11.56
19	52.0	50.3	50.1	53.8	- 1.7	- 1.9	+ 1.8	2.89	3.61	3.24
20	60.4	55.7	56.8	61.9	- 4.7	- 3.6	+ 1.5	22.09	12.96	2.25
21	58.6	55.1	56.7	57.7	- 3.5	- 1.9	- 0.9	12.25	3.61	0.81
22	58.3	60.7	58.1	62.6	+ 2.4	- 0.2	+ 4.3	5.76	0.04	18.49
23	49.5	54.3	52.1	46.6	+ 4.8	+ 2.6	- 2.9	23.04	5.76	8.41
24	57.4	56.0	55.7	57.4	- 1.4	- 1.7	0.0	1.96	2.89	0.00
25	62.7	56.9	61.2	64.3	- 5.8	- 1.5	+ 1.6	33.64	2.25	2.56
26	61.8	61.6	60.4	70.0	- 0.2	- 1.4	+ 8.2	0.04	1.96	67.24
27	62.3	57.8	59.6	62.3	- 4.5	- 2.7	- 0.1	20.25	7.29	0.01
28	58.9	56.6	57.1	60.2	- 2.3	- 1.8	+ 1.3	5.29	3.24	1.69
29	59.9	60.2	60.7	57.0	+ 0.3	+ 0.8	- 2.9	0.09	0.64	8.41
30	60.3	59.7	59.4	60.8	- 0.6	- 0.9	+ 0.5	0.36	0.81	0.25
Average	58.23	57.41	57.00	58.78				11.28	4.638	8.54

1/ 13 percent moisture in scoured wool.
2/ Differences of sample shrinkages from wholeffleece shrinkages.

In studying this table the following facts are observed:

1. All samples show a wide range of variability, the ordinary small random samples showing the greatest.

2. Samples restricted to wool from the exterior of the fleeces give an average shrinkage that is low compared with the shrinkage of the entire fleece. The exterior and interior samples, however, give an average shrinkage that is high compared with that of the entire fleece.

This test of small amounts gives us rather definite information that is perhaps more important than any we have yet obtained. The results are completely consistent in indicating that for these fleeces the interior of the fleeces has a higher shrinkage than the whole fleeces and the exterior has a lower shrinkage. The conclusion must be that any "random" sampling method confined to the outside portions of a fleece will tend to be in error by giving low shrinkages. This conclusion is in

agreement with the general trend of all our work, since our "random" sample shrinkages are almost invariably low when compared with commercial reports on the same wool. It appears that the random sampling method should be modified so as to include wool from the interior as well as the exterior of the fleece.

From the errors which are to be expected in the estimate of the shrinkage of a clip when the sampling is restricted to 30 fleeces, it appears that samples should be drawn from not fewer than 30 fleeces and preferably from more than 30 fleeces. It also appears that efforts should be made to make each sample heavier than has been our custom in order to reduce the possibilities of error inherent in small samples.

TESTS IN WHICH SHRINKAGES OF SAMPLES ARE COMPARED WITH THE SHRINKAGE OF THE BULK

Test on 76,013 Pounds of Graded Wool

Through the cooperation extended by a large mill engaged in worsted manufacture, an important comparative study on a lot of 76,013 pounds of wool as processed commercially and on the results of samples from the lot as processed in the laboratory was made possible. The lot consisted of 301 bags of graded Montana 1/2 Blood wool. From this lot 30 bags, or roughly 10 percent, were selected at regular intervals throughout the lot for use as a test portion. The manufacturer tested these 30 bags separately, and all information pertaining to the yield from this wool was kept separate.

These 30 bags were divided into three groups of 10 bags each, which in turn were sampled by different methods as follows:

1. Whole-Fleece Method: The 10 bags which made up one group were opened and from each the 5th, 15th, and 25th fleeces were taken to form a whole-fleece sample. These fleeces were combined to form a 30-fleece sample, representative of the 10 bags from which they were selected. The same procedure was followed in connection with the other two groups with the result that three sample bags of 30 fleeces each were shipped to the laboratory of the Service for testing. In order to accommodate the amount of wool to be processed to the size of the laboratory equipment, each bag was divided into two 15-fleece units and separate tests were run for each.

2. Random Method: This method was used to sample the remaining fleeces from the 3 groups of 10 bags each. Handfuls of wool were taken from various places on the surface of the fleeces so that the samples would contain wool, in proper proportions, from the shoulder sides, and back. These samples were combined to form a composite sample representative of each group. The third group was sampled in duplicate by the same method. Two operators selected wool at the same time. The composite

samples thus selected were also sent to the laboratory of this Service, and the fleeces processed in the mill. A representative of the mill also drew small samples from the random samples selected by the operator of this Service and these were tested in the laboratory of the mill.

3. Subsampling Method: After the random samples had been rendered homogeneous by being passed through a mechanical duster and opener in our laboratory, small subsamples were selected from them. The samples from which these subsamples were drawn ranged in weight from 7.6 pounds to 13.8 pounds. These subsamples represented 5 percent, by weight, of the random sample.

A comparison of the shrinkages obtained by the manufacturer on the bulk, on 10 percent of the lot, and the shrinkages of the different samples tested in the laboratory of this Service is shown in table 5.

Table 5. - Comparison of shrinkages of samples with bulk from 301 bags Montana graded 1/2 Blood

Lot or sample tested			Percent of shrinkage 1/	
			Blended subsamples	Bulk
			Percent	Percent
Mill results - 90 percent of lot or 271 bags			-	56.8
" " - 10 percent of lot or 30 bags			-	56.3
USDA laboratory (AMS)	1st 15 fleeces		55.4	55.5
" " "	2nd 15 fleeces		55.7	55.5
" " "	3rd 15 fleeces		56.9	57.1
" " "	4th 15 fleeces		55.5	55.1
" " "	5th 15 fleeces		57.0	57.1
" " "	6th 15 fleeces		57.3	56.9
" " "	1st 30 fleeces		55.6	55.5
" " "	2nd 30 fleeces		56.3	56.2
" " "	3rd 30 fleeces		57.1	57.0
Average	90 fleeces		56.3	56.2
RANDOM SAMPLES:				
USDA laboratory (AMS)	1st 10 bags		55.3	55.4
" " "	2nd 10 bags		54.6	55.3
" " "	3rd 10 bags		55.3 - 55.4 2/	54.9 - 55.6 2/
Total	30 bags		55.1	55.3
Mill laboratory 3/	1st 10 bags		57.7	
" "	2nd 10 bags		57.0	
" "	3rd 10 bags		57.3	
Total	30 bags		57.3	

1/ 12 percent moisture in scoured wool.
2/ Duplicate samples.
3/ The high shrinkages on the random samples scoured in the manufacturer's laboratory are due to the fact that the samples were conditioned and gained considerably in grease weight. This added moisture was removed in subsequent testing.

The following summarizes the information in the above table and gives the weights of the lot and samples.

Weights and Average Shrinkages of All Samples

	Weight in pounds	Percent of shrinkage
Mill shrinkage of 90 percent of lot or 271 bags	68,589	56.8
Mill shrinkage of 10 percent of lot or 30 bags	7,410	56.3
AMS laboratory shrinkage of 90 fleeces	770	56.2
AMS lab. shrinkage of subsample of 90 fleeces	15	56.3
AMS laboratory shrinkage of random samples	176	55.3
AMS laboratory shrinkage of random subsample	9	55.1
Mill shrinkage of random sample	4	57.3

The table reveals two mill shrinkages applicable to the lot, one of 56.3 percent on the 30 bags directly sampled and one of 56.8 percent on the remaining 271 bags. In connection with the whole-fleece samples, we find the limits of variations of the units of 15 whole fleeces from the mill shrinkages to be -1.7 percent to +0.8 percent. Corresponding limits of variation for the units of 30 whole fleeces are -1.3 percent to +0.7 percent. The maximum error of the laboratory shrinkage on 90 whole fleeces is -0.6 percent.

In connection with the laboratory random samples we find the limits of variation from the mill shrinkages to be -1.9 percent to -1.2 percent with a maximum error for the average of the random samples of -1.5 percent. The mill random samples have a range of variation from the mill shrinkage of from +0.2 percent to +1.4 percent. The high shrinkages on these samples are because they were conditioned in the manufacturer's laboratory and gained considerably in weight. This increased weight was removed in subsequent processing.

The shrinkages of the subsamples were satisfactory, the 15.4-pound subsample from the 90 fleeces being only 0.1 percent higher in shrinkage than the 90 fleeces and the 9-pound subsample from the random samples being only 0.2 percent lower in shrinkage than the random samples. The shrinkages of these 10-to 15-pound subsamples appear just about as reliable as the shrinkages of the 200-to 800-pound lots of wool from which they were taken.

In this particular test all three methods of sampling gave good results. Of the three methods the random method appeared most unsatisfactory, tending to give low results. On the basis of our present knowledge it appears that the random sampling method may be modified so that higher shrinkages and more satisfactory results may be obtained. However, even with the imperfect random sampling method used in this test, the errors are still so small that the method appears to have merit at present.

Amount of Residual Grease in Our Scoured Wool

Grease determinations were run on scoured samples of this lot of Montana graded 1/2 Blood wool. The 12 samples tested varied in grease content from 0.36 percent to 0.74 percent grease, with an average of 0.61 percent grease. These figures indicate that the wool is clean according to ordinary commercial standards without being overscoured.

Studies in Cooperation With Montana State College

In cooperation with the Animal Husbandry Department of the Montana State College, sampling and shrinkage investigations were conducted on several clips in Montana during the 1939 shearing season. Details of the tests on these Clips No. 3-39006, 3-39003 and 3-39013 are given below:

Clip No. 3-39006: The clip of wool in this test contained fleeces from four bands of sheep totaling about 6,000. In order to obtain a cross section of the whole clip, 10 bags spaced uniformly throughout the clip were opened and the fleeces graded. The grade composition of the 10 bags, containing a total of 316 fleeces, was found to be 84 percent Fine and 16 percent 1/2 Blood, by weight. The fleeces classed as 1/2 Blood were mainly on the high side of the grade and when tested their shrinkage was found to be much closer to that of the Fine wool than would have been the case had the fleeces approached the coarser side of the grade.

At the time of grading, each fleece was weighed and duplicate samples were drawn from it by the random method, one being taken by the representative of the Montana State College and the other by a representative from this Service. Throughout the grading every tenth fleece was set aside as it came to the grader. The 31 fleeces thus accumulated were shipped to a commercial scourer after they were sampled in duplicate. Hence, at the completion of the sampling operations there were duplicate hand samples from the 31 fleeces sent to the commercial scourer as well as from the fleeces that were returned to the lot.

As a result of this thorough sampling it was possible to obtain and to compare the shrinkages of the samples selected by the one operator with those of the other. A comparison also was made of the individual and average shrinkages of the samples selected by both operators with the shrinkage of the 31 fleeces from which they were drawn. The shrinkages of the random samples from the fleeces returned to the lot were also compared with the shrinkage of the 31 fleeces in the composite bag and with that of the random samples from them. It was found that the 31 fleeces in the composite sample bag, when tested commercially, showed a shrinkage of 56.9 percent, whereas, the average of the two samples selected from this bag and tested in our laboratory, showed a shrinkage of 54.3 percent, or a difference of -2.6 percent. However, when individual comparisons are made we find that the one sample was lighter than the composite bag by 2.1 percent, whereas, the other sample was even lighter and shrank 3.1 percent less than the bulk.

The results of the various tests and comparisons on this Clip No. 3-39006 are shown in table 6, page 30.

Clip No. 3-39003: The wool in this study was from a band of 1200 purebred Rambouillet Ewes of mixed ages. While the sheep were being shorn a count was kept of the fleeces and every fortieth fleece was set aside. At the completion of the shearing of the band there were 30 fleeces thus accumulated. These fleeces were sampled in duplicate by the random method and shipped to a commercial scourer to be tested for shrinkage.

The reports of the shrinkages of both the composite bag and the samples reveal that the average difference between the shrinkage of the samples and that of the bag was only 1.7 percent. Comparisons similar to those made with respect to the foregoing clip are shown for this Clip No. 3-39003 in table 7, page 31.

Clip No. 3-39013: As this clip was not available for sampling at the ranch, it was agreed that the owners would select one bag at random from their Crossbred fleeces and one from their Rambouillets. Accordingly, this was done and the two bags thus selected were shipped to a commercial scourer. The grading and sampling in duplicate of these two bags were done at the plant of a commercial scourer in the East. A separate test was made of the wool from the Rambouillet band and that from the Crossbred band. While the sample bags were tested in the mill, the samples from the bags were sent to the laboratory of this Service.

The average shrinkage of all samples selected from the Crossbred composite bag was found to be 4.2 percent less than that of the fleeces, whereas, the average of the shrinkages of the samples from the Rambouillet fleeces was practically in agreement with that of the whole bag.

In two instances the one sample had a shrinkage higher than that of the fleeces, while the other sample offset it with a correspondingly lower shrinkage. The most striking variation was found in the 1/2 Blood grade from the Crossbred wool. Here the shrinkage of the fleeces was 8.3 percent higher than the average shrinkage of the two samples. On examining the shrinkages of the three grades in this clip, it will be seen that the random sample shrinkages show a variation from one grade to another that is normal and to be expected. The shrinkages reported on the bags by the commercial scourer, however, do not follow this logical order, inasmuch as the 1/2 Blood shrinkage is higher than that of the Fine. We are led to believe that, in this instance at least, the shrinkages of the samples are a more accurate indication of the shrinkages of the grades in the clip than are the fleece results.

The results of the tests on this Clip No. 3-39013 are shown in table 8, page 32.

Test on 18,000 Fleeces of Wyoming Wool

To represent this clip of 18,000 fleeces, 12 bags of Ewe wool and 3 bags of Yearling wool, uniformly spaced throughout the clip, were selected. The 15 bags thus taken amounted to about 2 1/2 percent of the clip. To determine whether the clip could be as well represented by a smaller number of bags, the 12-bags of Ewe wool were divided into an 8-bag lot and a 4-bag lot. The 3-bag, 4-bag, and 8-bag sample units were opened and graded separately.

Duplicate samples were drawn from all fleeces by the random method. These samples - grades and lots being kept separate - were shipped to the AMS wool scouring laboratory for testing. The fleeces - grades and lots similarly kept separate - were shipped to a commercial wool scourer. As the equipment of the commercial concern was not adapted to testing small amounts of wool, all off-sorts such as tags and dirty locks were subsequently forwarded to Washington for testing.

A comparison of the shrinkages of the samples with those of the bulk is shown in table 9, page 19.

Table 9.- Comparison of shrinkages of samples from Clip No. 2-39012 with those of the bags from which they were selected

Grade and lot	Shrinkage 1/		Difference		Grease Weights	
	Bags	Samples			Bags	Samples
	Percent	Percent	Percent		Pounds	Pounds
FINE:						
8-Bag	65.2	64.6	- 0.6		542	32
4-Bag	67.1	66.3	- 0.8		363	27
3-Bag	69.9	66.4	- 3.5		140	6
Average	66.5	65.5	- 1.0	Total	1045	65
1/2 BLOOD:						
8-Bag	63.7	63.1	- 0.6		1015	58
4-Bag	63.1	62.7	- 0.4		332	29
3-Bag	66.5	62.6	- 3.9		364	12
Average	64.2	62.9	- 1.3	Total	1711	99
3/8 BLOOD:						
8-Bag	60.0	59.8	- 0.2		487	29
4-Bag	59.4	59.3	- 0.1		323	27
3-Bag	62.7	58.7	- 4.0		294	8
Average	60.5	59.5	- 1.0	Total	1104	64
1/4 BLOOD:						
8-Bag	57.0	55.5	- 1.5		319	22
4-Bag	57.3	55.8	- 1.5		195	16
3-Bag	56.3	55.1	- 1.2		127	4
Average	56.9	55.6	- 1.3	Total	641	42
LOW 1/4 BLOOD:						
8-Bag	59.2	57.5	- 1.7		88	8
4-Bag	66.7	54.1	-12.6		57	1
3-Bag	62.2	53.7	- 8.5		59	2
Average	62.2	56.4	- 5.8	Total	204	11
COMMON & BRAID:						
8-Bag	57.1	55.2	- 1.9		80	10
4-Bag	53.7	48.2	- 5.5		49	4
3-Bag	-	-	-		-	-
Average	55.8	53.1	- 2.7	Total	129	14
LOW 1/4 & C & B:						
8-Bag	58.2	56.2	- 2.0		138	18
4-Bag	60.7	50.6	-10.1		106	9
3-Bag	62.2	53.7	- 8.5		59	2
Average	59.2	54.4	- 4.8	Total	333	29
ALL GRADES:						
8-Bag	62.1	61.0	- 1.1		2531	159
4-Bag	63.0	60.7	- 2.3		1319	108
3-Bag	64.3	61.5	- 2.8		984	32
Average	62.6	60.9	- 1.7	Total	4834	299

1/ 13 Percent moisture in scoured wool

In calculating the shrinkages in the foregoing table, string and paint clips were considered as total loss whereas the shrinkage of low and stained wool was included. All shrinkages are based on 13 percent moisture in scoured wool. All average shrinkages are properly weighted.

A study of the foregoing data shows that:

1. The shrinkages as a whole were in satisfactory agreement with the mill shrinkages, the average of all samples being only 1.7 percent lower than the mill shrinkage on the entire 15 bags.

2. Shrinkages for individual grade samples were at times at considerable variance with those for commercial grade lots. These variations may be explained either on the assumption that the sample shrinkages are too low or that the mill shrinkages are too high. In one instance in which the differences were particularly marked the evidence points to the greater accuracy of the sample shrinkage. In the case of the samples drawn from the 4-bag lot, the 1/4 Blood sample showed a shrinkage of 55.8 percent, the Low 1/4 Blood sample a shrinkage of 54.1 percent, and the Common and Braid sample a shrinkage of 48.2 percent; whereas, the commercial bulk shrinkages on the same grades were respectively 57.3 percent, 66.7 percent, and 53.7 percent. It is a matter of experience that almost invariably coarser wools have lower shrinkages. On this basis the drop in the shrinkages of the random samples is reasonable and consistent. On the other hand, we find that the bulk shrinkage of the Low 1/4 Blood wool instead of dropping a few percent below the bulk shrinkage (57.3 percent) of the 1/4 Blood wool, as would be expected, increased by 9.4 percent to a shrinkage of 66.7 percent. This figure is practically as high as that for the bulk shrinkage on the Fine wool in the 4-bag lot. Such variations among the shrinkages of different grades of wool are not reasonable, particularly in view of the fact that the shrinkages of the samples indicated consistent and reasonable decreases from the higher to the lower grades. These large variations among the commercial bulk shrinkages on the different grades are very probably due to an attempt to scour small quantities of wool in machinery designed to handle much larger quantities.

3. The individual grade shrinkages and the average shrinkage of the samples of the 3-bag lot of Yearling wool are not in as good agreement with the corresponding bulk shrinkages as in the case of the 4-bag and 8-bag lots of Ewe wool. This is probably due in part to the fact that the Yearling wool contained a higher percentage of tags than did the Ewe wool.

If, as is generally assumed, a large enough proportion of tags and other wool that has heavy shrinkage is not included in the selections by the random sampling method, it follows that the difference in the shrinkage of the random sample from the very taggy Yearling wool and the shrinkage of the bulk wool would be much greater than the difference in the shrinkage of the random samples from the less taggy Ewe wool and that of the bulk.

4. Practically the same results would have been obtained if instead of sampling 15 bags, the sampling had been confined to 5.

In addition to the mill shrinkages actually determined from the wool under test, there was available a commercial estimate on the shrinkage of this particular clip. The shrinkage for the entire clip was estimated to be 59.6 percent. It is interesting to note that our sample shrinkage on the entire clip was 60.9 percent, which is just about midway between the mill shrinkage determination of 62.6 percent and the commercial shrinkage estimate of 59.6 percent.

The results of this experimental sampling project have been encouraging and indicate that our methods are accurate enough to furnish useful information.

Test on 24,000 Fleeces of Utah Wool

After the shearing of this clip, entire bags were selected at intervals. In this way a total of 16 entire bags was selected. These bags were opened and duplicate random samples drawn from each fleece. Shrinkage determinations on the samples were made in the AMS wool scouring laboratory. For purposes of comparison with the results on the samples there are available on this clip an estimated commercial shrinkage on 135,479 pounds of the Fine wool, and an actually determined mill shrinkage on 21,820 pounds of the wool without regard to grade. A comparison of the various shrinkages follows:

	Percent
Estimated shrinkage of 135,479 pounds of Fine wool	65.9
Sample shrinkage of Fine wool	62.44
Actual mill shrinkage of 21,820 pounds ungraded wool	66.6
Average shrinkage of all samples	60.9

In examining these comparisons, striking differences are seen between the results of tests on samples and the results otherwise obtained on the bulk. Information available on the bag and clip weights at point of origin in the West and at destination in the East shows a gain in transit or after arrival of 4.73 percent. This gain in weight occurred before the mill shrinkage test on 21,820 pounds of the clip had been run, but subsequent to the sampling of the clip for laboratory test purposes. It appears, therefore, that these large variations between sample shrinkages and bulk shrinkages might be partly due to an increased moisture content in the bulk of the wool. If the bulk shrinkages are recalculated on the assumption that the original grease bulk weight should be reduced by 4.73 percent to make the bulk shrinkages comparable with the sample shrinkages, the following comparisons are obtained:

	Percent
Estimated shrinkage of 135,479 pounds of Fine wool	64.2
Sample shrinkage of Fine wool	62.4
Actual mill shrinkage of 21,820 pounds ungraded wool	65.0
Average shrinkage of all samples	60.9

It will be noted that the sample shrinkages still show considerable variation from the bulk shrinkages although better agreement has resulted from the recalculation. It is also interesting to note that due solely to the increase in weight of the clip, its shrinkage appears to have increased from 65.0 percent at the ranch to 66.6 percent at the mill.

WHOLE-FLEECE SAMPLES, RANDOM SAMPLES AND ALIQUOT SUBSAMPLES COMPARED AS A MEANS OF ESTIMATING SHRINKAGES

Tests on Bags No. 12, 134 and 133 From Bureau of Animal Industry

In connection with these three bags of wool, it was decided to try several sampling methods that appeared to have particular merit. The objective was to obtain samples that would have shrinkages strictly comparable with each other and with the shrinkage of the entire bag. Accordingly, the random, whole-fleece, and subsample methods were used. These methods have been described previously.

The first step in this experiment was to grade the fleeces in each bag. The fleeces were not all of the same grade consequently, in making up whole fleece samples to represent the individual bags, it appeared necessary to choose "sets" of fleeces containing as nearly as possible the same proportionate number of fleeces of each grade as in the original bag. Thus, if the original bag contained about 25 percent Fine, 50 percent 1/2 Blood, and 25 percent 3/8 Blood fleeces, each set of whole fleeces was chosen to contain the same proportions of the different grades. After the sets of whole fleeces were decided upon, the procedure was as follows:

Each fleece in the set was sampled heavily by the random method and the samples combined to make a random sample representative of the set.

The remainder of the fleece was opened, paint, burrs, and tags were removed; and then it was dusted. From each dusted fleece a 5 percent subsample was taken. These were combined to make a 5 percent sample representative of the entire set.

The remainder of each dusted fleece was scoured as a unit, since it appeared desirable to get information on the individual fleeces. By calculation it was possible to combine the shrinkages of the individual fleeces to obtain the shrinkage of the set as based on the bulk of the fleeces.

A comparison of the shrinkages of the various samples and sets of fleeces in the three bags is given in table 10.

Table 10. - Shrinkages of samples and sets of fleeces

Bag No. and breed	Sets of whole fleeces	Percent of shrinkage 1/			
		Whole fleeces	Random samples	10 percent subsample of random sample	5 percent subsample of whole fleece
		Percent	Percent	Percent	Percent
BAG NO. 12: 30 Targhee Fleeces	1-8 Fleeces	56.8	55.9	52.9	58.1
	2-8 "	57.6	57.1	56.1	58.0
	3-7 "	54.7	53.6	54.3	55.1
	4-7 "	56.4	55.6	54.3	56.8
	Entire Bag	56.4	55.6	54.4	57.1
BAG NO. 133: 30 Columbia Fleeces	1-5 Fleeces	49.1	49.8	49.1	48.6
	2-5 "	48.1	49.9	49.0	48.1
	3-5 "	45.6	44.0	42.6	46.6
	4-5 "	46.0	45.6	45.5	45.5
	5-5 "	44.6	43.9	42.7	45.1
	6-5 "	46.7	47.3	46.8	46.5
	Entire Bag	46.6	46.8	46.0	46.7
BAG NO. 134: 30 Corriedale Fleeces	1-8 Fleeces	48.5	48.6	49.8	48.1
	2-5 "	49.3	48.3	47.2	49.5
	3-6 "	46.9	47.8	48.2	47.0
	4-5 "	43.8	43.9	43.4	44.1
	5-6 "	46.6	45.8	44.3	46.2
	Entire Bag	47.1	47.1	46.9	47.1
Average of 3 bags		50.0	49.8	49.1	50.3

1/13 percent moisture in scoured wool.

In examining the above table the following points become apparent:

1. On all three bags the random samples gave satisfactory results, the greatest variation from the bag shrinkage occurring in the case of Bag No. 12, with a variation of - 0.8 percent. It is interesting to note that in this bag of relatively Fine wool the proportion of tags was higher than in the other two bags.

2. The 10 percent subsamples drawn from the random samples did not give particularly good results. The explanation for this probably lies in the fact that the subsamples were rather small, perhaps too small for accurate determinations.

3. The 5 percent subsamples from the whole fleeces gave fairly good results, the greatest individual variations being 1.3 percent and the greatest variation from an entire bag being + 0.7 percent.

4. The shrinkages of the sets of whole fleeces often showed appreciable variations from the shrinkages of the entire bags. These variations ranged in magnitude from + 2.5 percent to - 3.3 percent.

A statistical analysis of the shrinkages of the individual fleeces in these bags was made to obtain an indication of the number of whole fleeces needed to afford a reliable indication of the shrinkage of a clip. It was concluded that to determine the shrinkage for a grade within a clip, a sample of 30 whole fleeces, selected at random throughout any particular grade, would be needed and the result would have an accuracy of ± 2 percent for a probability of 99 percent. With such a large whole-fleece sample necessary for the indicated accuracy, it seems more promising to proceed with attempts to develop and improve the random sampling method. It would then be possible to sample larger numbers of whole fleeces without acquiring an impracticably large bulk of wool.

The tests on these three bags are one more indication of the desirability of modifying the random sampling method. Although there will be room for improvement in the random sampling method used in these tests, the greatest error occasioned in estimating the shrinkage of a bag was only - 0.8 percent. Further attempts are planned to improve random sampling tests.

Tests with the subsample method indicated that with small subsamples of 1/2 to 3/4 pounds, the shrinkages might be considerably in error but that with subsamples amounting to 6 or 7 pounds in weight, the shrinkages would be reliable to ± 0.7 percent.

Comparison of Shrinkages of Subsamples With Bulk

In order to obtain additional information relative to the reliability of subsampling, 10 percent subsamples were drawn from five dusted and blended fleeces. The shrinkages are compared in table 11.

Table 11. - Shrinkages of subsamples and whole fleeces

Fleece No.	Percent of shrinkage 1/		Difference
	Bulk	10 percent subsample	
	Percent	Percent	Percent
3337-A	51.6	51.1	- 0.5
3328-A	54.1	53.6	- 0.5
2998-K	54.8	55.4	+ 0.6
3005-K	55.2	54.8	- 0.4
2993-K	61.7	62.1	+ 0.4
Average	55.5	55.4	- 0.1

1/ 13 percent moisture in scoured wool.

In these tests it was found that the highest difference between the shrinkage of a subsample and of its corresponding fleece was 0.6 percent. Furthermore, the average shrinkage of the five subsamples was only 0.1 percent lower than the average shrinkage of the five fleeces. It appears evident that reliable results can be obtained by scouring 10 percent subsamples of 4-pound to 10-pound samples of wool, provided the samples are dusted and blended thoroughly before the subsamples are taken.

Variations Between Duplicate Random Samples

The following are the variations found as a result of conducting 60 tests involving duplicate samples selected from Montana clips:

Number of tests	Variations between samples Percent
19	0.0 to 0.5
14	0.6 to 1.0
11	1.1 to 1.5
7	1.6 to 2.0
9	2.1 to 4.5

A similar experiment was carried on in connection with Utah wool and the results obtained are as follows:

Number of tests	Variations between samples Percent
2	0.0 to 0.5
4	0.6 to 1.0
3	1.1 to 1.5
1	1.6 to 2.0
2	2.1 to 2.5
2	2.6 to 3.0
2	3.1 to 3.5

The majority of the variations between duplicate samples are within the 2 percent variation limit accepted as a goal. However, there are some variations that are seriously large. Statistical analyses have indicated that these larger variations are to be expected as a result of oversimplifying the sampling problem and drawing too small samples from too few fleeces. Larger samples drawn from a greater number of fleeces will yield better results.

INFLUENCE OF OFFSORTS ON SHRINKAGE

Tests in Cooperation With a Commercial Scourer

As a result of the practice in this country of placing tags and dirtier portions inside of the fleeces when preparing them for market, the wool on the exterior is usually cleaner and of lower shrinkage than that of the interior. When the amount of tags in a clip is small the influence on shrinkage is relatively unimportant. However, there are many clips which do exhibit considerable nonuniformity traceable directly to the inclusion of a relatively large amount of tags within the fleeces. In view of this it is necessary when sampling to take into account the relationship of the exterior to the interior of the fleeces.

Tests were made on seven lots of wool and information obtained regarding the amounts of tags and offsorts and their influence on the shrinkage of the lots. The outer portions of the fleeces in each of these lots were sampled by the random method. By comparing the shrinkages of the samples with the shrinkage of the bulk, including and excluding offsorts, it was possible to determine just how greatly the tags and dirtier portions affected the shrinkage. The results of the tests are shown in table 12.

Table 12. - Shrinkages including and excluding offsorts

Lot No.	Percent of shrinkage 1/			Difference		
	Commercial bulk		Random sample			
	Exclusive offsorts	Inclusive offsorts				
	A	B	C	B-A	C-A	C-B
	Percent	Percent	Percent	Percent	Percent	Percent
3-39003	50.3	51.3	49.6	+ 1.0	- 0.7	- 1.7
3-39006	55.7	56.9	54.6	+ 1.2	- 1.1	- 2.3
3-39013:						
Crossbred	56.6	57.6	53.4	+ 1.0	- 3.2	- 4.2
Rambouillet	65.9	67.6	67.6	+ 1.7	+ 1.7	0.0
2-39012:						
8-Bag Ewes	61.1	62.1	61.0	+ 1.0	- 0.1	- 1.1
4-Bag "	62.2	63.0	60.7	+ 0.8	- 1.5	- 2.3
3-Bag Yrlgs.	62.7	64.3	61.5	+ 1.6	- 1.2	- 2.8
Average	59.2	60.4	58.3	+ 1.2	- 0.9	- 2.1

1/ 13 percent moisture in scoured wool.

The bulk shrinkages including the offsorts average 1.2 percent higher than the bulk shrinkages excluding them. The average sample shrinkage is 0.9 percent lower than the bulk shrinkage excluding offsorts, but 2.1 percent lower than the bulk shrinkage including them. It appears impossible to arrive at any other conclusion than that at least part of the difference between sample and bulk shrinkages must be due to restricting the sampling to the outermost and more tag free portions of the fleeces. A revision of the sampling method will in all probability not entirely solve the problem, but it should help to some extent to produce samples without the consistently "minus" shrinkage error we have found.

SUMMARY

(1) Subsamples having a minimum weight of from 6 to 7 pounds drawn from thoroughly blended wool were shown to have a shrinkage within ± 0.7 percent of the bulk from which they were drawn. This has been and should hold true no matter how heterogenous the original wool, and even if the subsample amounts to only 2 percent of the weight of the original wool.

(2) From experiments on three bags of Montana wool, indications are that 30 whole fleeces selected at random from a similar lot of a single grade will give the shrinkage of that lot with an accuracy of ± 2 percent and a probability of 99 percent.

(3) Analysis of the reports on commercial tests, investigation of the commercial procedure, and study of our results show that it is not feasible to test small samples in large scale commercial equipment, The accuracy of results on small portions so scoured is in doubt. Since commercial shrinkages on small quantities have in the past formed the basis with which our sample shrinkages have been compared, it is felt that some of the errors attributed to our tests may be too high. On the other hand, there has been rather consistent agreement between the shrinkages of samples obtained in the wool laboratory and those obtained by commercial scourers when the quantities of wool tested by the scourers amounted to at least 200 pounds.

(4) It has been demonstrated that there is a tendency for shrinkages to be low when samples have been selected by the random sampling method as previously used. As a result of our studies it is felt that this is due to the fact that the tags and heavy shrinking wool have not been represented in the sample in proper proportions. Experiments are in progress with a view to modifying the random sampling method so that it will give more accurate results.

(5) Statistical analyses of the variability of shrinkage of fleeces among three breeds of sheep indicate that the composite bag method of representing clips is based on an oversimplification of the sampling problem. This is especially true when an attemp is made to determine from a composite bag of 30 fleeces the shrinkage of the individual grades in a clip representing four or more grades.

Table 6. - Comparison of shrinkage of samples selected from composite bag and clip with shrinkage of entire bag (Including offsorts)

Clip No. 3-39006
Lot No. 3165

Grade and Sample	Shrinkage 1/				Percent of Difference			Gross Weight		
	E. & L. Bag	Sample No. 1	Sample No. 2	Ave.	Sample No. 1	Sample No. 2	Ave.	E. & L. Bag	Sample No. 1	Sample No. 2
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Pounds	Pounds	Pounds
FINE										
Composite Bag 31 Fleeces	56.9	54.8	53.8	54.3	-2.1	-3.1	-2.6	305	12.3	9.8
FINE										
1st 100	"	55.8	55.0	55.3	-1.1	-1.9	-1.6	"	11.9	20.9
2nd 100	"	54.0	53.7	53.8	-2.9	-3.2	-3.1	"	12.6	20.6
3rd 116	"	55.8	56.6	56.2	-1.1	-0.3	-0.7	"	16.5	17.5
All 316	"	55.3	55.0	55.1	-1.6	-1.9	-1.8	"	41.0	59.0
1/2 BLOOD										
All 316	-	50.9	50.2	50.5	-	-	-	-	5.6	6.6
Total Fine and 1/2 Blood	56.9	54.7	54.5	54.6	-2.2	-2.4	-2.3	305	46.6	65.6

In this test 10 bags containing 316 fleeces were sampled. Every 10th fleece was set aside to form a composite bag of 31 fleeces. The random samples drawn from this composite bag are strictly comparable with it. Random samples were selected from the remaining fleeces in approximately equal groups. The shrinkage of these samples may be compared with the shrinkage of the composite bag and the composite bag samples since the composite bag is supposed to be representative of the entire 10 bags in the test.

1/ 13 Percent moisture in scoured wool

Table 7. - Comparison of shrinkage of samples selected from composite bag and clip with shrinkage of entire bag (Including offsorts)

Clip No. 3-39003
Lot No. 2983

Grade and Sample	Shrinkage 1/				Percent of Difference			Gross Weight		
	E. & L. Bag	Sample No. 1	Sample No. 2	Ave.	Sample No. 1	Sample No. 2	Ave.	E. & L. Bag	Sample No. 1	Sample No. 2
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Pounds	Pounds	Pounds
FINE	51.3	48.8	50.4	49.6	-2.5	-0.9	-1.7	258	12.6	11.2

1/ 13 Percent moisture in scoured wool

Table 8. - Comparison of shrinkage of samples selected from composite bag and clip with shrinkage of entire bag (Including offsorts)

Clip No. 3-39013
Lot No. 3035-A-B

Grade and Sample	Shrinkage [1/]				Percent of Difference			Gross Weight		
	E. & L. Bag	Sample No. 1	Sample No. 2	Ave.	Sample No. 1	Sample No. 2	Ave.	E. & L. Bag	Sample No. 1	Sample No. 2
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Pounds	Pounds	Pounds
CROSSBRED										
FINE	59.5	57.5	57.5	57.5	-2.0	-2.0	-2.0	63.0	2.4	1.4
1/2 BLOOD	61.6	52.5	54.7	53.3	-9.1	-6.9	-8.3	108.1	4.6	2.9
3/8 BLOOD	50.6	49.9	51.1	50.3	-0.7	+0.5	-0.3	78.7	3.0	1.8
TOTAL	57.6	52.9	54.3	53.4	-4.7	-3.3	-4.2	249.8	10.0	6.1
RAMBOUILLET										
FINE	68.3	66.4	66.6	66.5	-1.9	-1.7	-1.8	105.9	4.2	3.3
1/2 BLOOD	67.2	70.4	66.0	68.4	+3.2	-1.2	+1.2	197.1	6.5	5.5
TOTAL	67.6	68.8	66.2	67.6	+1.2	-1.4	0.0	303.0	10.7	8.8

[1/] 13 Percent moisture in scoured wool

UNITED STATES DEPARTMENT OF AGRICULTURE
U.S. Agricultural Marketing Service

PROGRESS IN WOOL SHRINKAGE RESEARCH DURING YEAR 1940

By Warner M. Buck, Specialist in Marketing Wool,
and George C. LeCompte, Associate Wool Technologist

Washington, D. C.
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INTRODUCTION

Wool as it comes from the sheep contains relatively large quantities of extraneous substances, such as natural grease, dried perspiration, soil, sand, vegetable matter, etc. As this extraneous matter has originally cost the buyer just as much per pound as has the clean fiber content, its elimination by cleansing the wool would represent a serious loss to him, unless there were a compensating increase in the price for the smaller amount of cleaned wool remaining. It is evident, therefore, that the amount of impurities carried by grease wool has considerable influence on its market value. A good illustration of the importance of scouring loss or shrinkage as a price determining factor is seen when Fine Territory wool, which sells in the market on a basis of $1.00 per scoured pound, decreases in grease value 1 cent per pound for each 1 percent increase in shrinkage.

Producers have recognized their need for reliable information pertaining to shrinkage, so that they can market their clips to better advantage. In response to an insistent demand from them and their organizations, the Agricultural Marketing Service inaugurated a research project in 1937, the objective of which is the development of a quick and dependable method of sampling clips or lots of wool for shrinkage determination.

Attempts have been made from time to time by commercial concerns to select small samples of wool, test them for shrinkage, and apply the shrinkages to the lots from which the samples had been taken. The method has not proved consistently reliable, and its failure appears to have been caused in two possible ways: First, the selection of the samples by trained men who relied upon their judgment in picking the wool that went into them; and secondly, the probable absence of control in the testing procedure. In a test of this kind, the samples would be in error in proportion to the error in the judgment of the sampler. It has been shown, however, that with the subordination of personal judgment and the substitution of a systematic

1/ Research conducted by the Agricultural Marketing Service in cooperation with laboratories of colleges, universities, State experiment stations of Montana, Wyoming, Utah, and Colorado, and various woolen mills.

method of sampling, progress is made in correcting this error. It has also been demonstrated that if laboratory control is practiced, there will be a commensurate increase in the accuracy of the results of the tests.

In 1938, checks were first made by the Agricultural Marketing Service of the shrinkages of samples against the shrinkage of the wool from which they were taken. In that year the shrinkages of the samples from 20 individual bags were compared with the shrinkage of the wool itself. The extreme differences of these sample shrinkages from bulks were -1.2 percent and -6.5 percent, with an average difference of -3.18 percent. This average difference of -3.18 percent, coupled with large individual differences, was not satisfactory. It is interesting to note that in all the tests made in 1938, samples had shrinkages lower than that of the wool from which they were taken.

In 1939, similar comparisons were made of the shrinkages of 21 separate quantities of wool. Although the results were more satisfactory than in the preceding year, the differences between sample shrinkages and bulk shrinkages ranged from 0.0 percent to -12.6 percent, with an average of -2.7 percent. In every instance but one, the sample shrinkages proved to be lower than the corresponding bulk shrinkages. A careful study of the results of this work indicated quite clearly that the still unsatisfactory results obtained in 1939 could be explained by the fact that relatively small quantities of wool were scoured in standard commercial equipment and that the grades of wool were represented by samples from only a few fleeces.

The changes found to be necessary through former experiments, were introduced, and therefore the results obtained in 1940 are satisfactory. Despite encouraging improvement, however, the work is still considered as of a research nature.

METHOD OF APPROACH

To date, work has been directed primarily toward obtaining basic information regarding the closeness with which hand samples would indicate the shrinkage of the wool from which they were drawn. This preliminary work was necessary, so that any method of sampling that might be developed would have a sound basis. In conducting these studies, various methods of sampling were tried, and the results indicated that the selecting of wool at random from tied fleeces was the most practical procedure. Extended investigations into the selecting of particular body sorts definitely show the difficulty that is experienced when attempts are made to locate such parts. The only time a definite part of a shorn fleece can be located is when the fleece drops from the animal in the shearing pen. This difficulty makes such a method impractical from a commercial standpoint.

Results obtained through the random hand-sampling method furnish evidence that the method has merit and that the information so obtained presents a minimum of bias. Progress can be made in further eliminating bias by placing the sampling upon a complete statistical basis, and by establishing the variability of the different types of domestic wool which it may be necessary to sample. With information regarding the variability

of the wool to be sampled, and with the upper limits of permissible error established, it should be possible by statistical methods to state definitely how many bags or fleeces of wool must be sampled and how many hand samples must be drawn, in order to represent the bulk within the previously decided upon limits of error for any desired probability. Properly handled, such a sampling method should lead to consistently accurate shrinkage determinations.

RANDOM HAND SAMPLING

The method followed in selecting samples on which reports are made herein may be designated as "random hand sampling." This method of sampling calls for the taking of a number of handfuls of wool, weighing possibly 1/20 of a pound each, from several locations in the fleeces. Insofar as possible, personal judgment is eliminated, and no studied attempt is made to make representative selections from the fleeces. According to the findings of the Agricultural Marketing Service, the process of taking wool at random produces a composite sample that is more representative than would be obtained by exercising personal judgment in the selection of the wool.

Of considerable importance with respect to random sampling is the fact that tests have proved that samplers with little wool experience were able to obtain samples that represented the bulk just as accurately as experienced men were able to obtain. This indicates that no great amount of training is necessary to enable a person to obtain representative samples, providing the requirements of the method are strictly adhered to. Moreover, in the long run, inexperienced men may prove more dependable as samplers, since they would not discern the difference in the wool that would be apparent to the eyes of trained samplers, and therefore, they would not be influenced in the selection of the samples.

EFFECT OF OFFSORTS ON SHRINKAGE

The accuracy with which samples selected by hand from tied fleeces will represent a lot of wool, has been questioned on the grounds that the heavy shrinking parts of the fleece, which are usually found inside the bundled fleece, will not be represented in the proper amounts in the samples. It has been thought that, in consequence, the shrinkages of the random samples would be substantially lower than the shrinkage of the wool from which the samples were taken. In order to determine the validity of this contention, a number of experiments were conducted to find the maximum variation in shrinkage that would occur by excluding heavy shrinking offsorts. The majority of the tests were made on fine and 1/2-blood territory wool, and the results indicate that no serious problem is presented by offsorts in this kind of wool when it is properly prepared.

In the 21 lots of wool tested during the last season, the percentages of offsorts made in sorting ranged from a low of 1 percent to a high of 6 percent, with an average of 2.8 percent for all lots. The increase in the shrinkage of the various lots tested, due to the inclusion of the offsorts

in the calculations, ranged from 0.4 percent for the well-prepared wools to 1.9 percent for the "taggy" lots. The average increase for all lots tested was found to be 1.2 percent. This would indicate that even if random hand samples were drawn so as to include no tags, britch, or heavy-stained wool at all, the maximum difference caused by the exclusion of these offsorts would be only 1.9 percent. Tags and heavy-stained sorts are found to some extent in all samples, so that in the course of the customary testing the possible discrepancy due to failure to include them would be inconsequential.

Full details in connection with comparisons made for the purpose of indicating the influence of offsorts on shrinkage are shown in table 1, page 12.

IMPORTANCE OF STANDARDIZED TESTING

The Agricultural Marketing Service has conducted studies which show that successive samples drawn from a lot of grease wool may give different shrinkage results when tested in different laboratories. These differences may be ascribed to two causes: An actual difference in the samples, and imperfect methods of measuring in the laboratory. In order to determine to what extent variations in laboratory technique alone might affect shrinkages, samples that were made as nearly alike as possible by thorough blending, were sent to seven laboratories to be tested for shrinkage in accordance with their respective methods. Comparisons of the reports made by these laboratories show a need for the standardization of methods of testing and the introduction of controlled procedure in laboratory technique, so that greater uniformity in results may be attained and differences reduced to the point where they will be of little commercial significance.

A brief summary of the results of this interlaboratory test, together with adjustments made through computation and subsequent tests of the scoured product, is presented in the following table.

Table 2 - Comparison of original and corrected sample shrinkages

Cooperating Laboratory	No. of samples tested	Original average shrinkage reported	Average shrinkage corrected to same Moisture and impurities content	Changes in shrinkages originally reported
		Percent	Percent	Percent
No. 1	8	59.87	58.41	-1.46
No. 2	4	58.23	57.99	-0.24
No. 3	4	58.97	57.76	-1.21
No. 4	4	57.79	57.94	+0.15
No. 5	4	60.00	58.36	-1.64
No. 6	4	57.04	57.71	+0.67
No. 7	4	58.21	58.37	+0.16
No. 1	3	60.13	58.15	-1.98
Average		58.87	58.12	-0.75
Range		3.09	0.70	

Originally there was a maximum difference of 3.09 percent between the shrinkages reported by the various laboratories, whereas after adjustments to the same base for residual moisture and impurities had been made, the difference was reduced to 0.70 percent. It has been concluded as a result of this interlaboratory test that if proper equipment is used and the testing procedure controlled, differences in shrinkage results due to laboratory technique will be minimized. Shrinkage research will thus be advanced by a coordination and standardization of testing methods in all laboratories engaged in determining shrinkage.

STANDARDS FOR MOISTURE CONTENT AND IMPURITY CONTENT

When determining the shrinkage of samples, control must be exercised in connection with several factors. In order that all tests may be conducted on the same bases, the wool laboratory of the Agricultural Marketing Service has set up standards for its own use for the following factors:

1. Moisture content of grease wool samples where it appears proper to use such a standard;

2. Moisture content of scoured wool samples;

3. Residual impurity content of scoured wool samples.

It is of obvious advantage to have standards for the amounts of moisture and impurities that are allowed in scoured wool. For grease wool, however, there is some justification for using the moisture content of the sample when it is drawn. If we assume that a sample can be drawn from a clip and actually represent that clip, it is evident that the shrinkage should be based upon the weight of the sample at the time it is drawn, since this weight reflects the moisture content of the sample at that time. A clip of wool may lose or gain in weight thereafter, and for that reason the shrinkage may vary from time to time. The original sample shrinkage will agree with the shrinkages of samples drawn later only if the latter are based upon the same moisture content. For this reason, it is believed advisable to determine the moisture content of grease wool samples when they are originally drawn, and if the shrinkages are based on the original grease weight, to state the moisture content of that original grease weight. All other things being equal, subsequent sample shrinkages based upon grease weights calculated according to the original moisture content, will be in agreement with the original sample shrinkage.

If a sample of wool, however, is brought into a laboratory without particular weight or moisture content having been determined at the time it was drawn, it would seen proper to base the shrinkage of such sample upon grease weight calculated at a standard moisture content.

During the last year, tests have been run on grease samples as they were received in the wool laboratory of the Agricultural Marketing Service. The extreme values found were 4.79 percent and 14.74 percent moisture content. The importance of using a standard moisture content for grease wool except where such use is contra-indicated, is apparent.

CHANGE IN LABORATORY STANDARDS

Attention was paid during the last year to the amounts of residual impurities found in scoured wool from different sources. As a result of the tests that were made, it appeared advisable to revise the standards that had been used in 1939. These revised standards contain a slight change with respect to allowable petroleum ether extract. The previous requirements for alcohol extract, ash, and moisture in scoured wool are retained. Investigations have been made of the amounts of residual impurities in scoured wool as measured by the loss in weight experienced in rescouring. Such tests are simpler and more rapid than the usual chemical tests, and the results obtained thereby have been found to be satisfactory. In view of this, a limit has been tentatively set for the loss in weight through rescouring that scoured wool should not exceed. The revised tentative laboratory standards are as follows:

1. The standard moisture content for grease wool, in the absence of information regarding the original moisture content on the weight of the sample when drawn, shall be 12 percent.

2. The standard moisture content for scoured wool shall be 12 percent.

3. The scoured wool shall not contain more than 0.50 percent petroleum ether extract or grease.

4. The scoured wool shall not contain more than 1.0 percent alcohol extract after the grease has been extracted with petroleum ether.

5. The scoured wool shall not contain more than 1.0 percent ash.

6. The scoured wool shall not lose more than 0.60 percent of its bone-dry weight when subjected to rescouring.

The adoption of these tentative standards for use in the wool laboratory of the Agricultural Marketing Service insures that shrinkages will be calculated on a uniform basis.

TESTS PERFORMED TO ASCERTAIN SAMPLE-BULK RELATIONSHIP

The accuracy with which the shrinkage of a sample will reflect the shrinkage of the clip or lot from which it is drawn can best be determined by a comparison of the results obtained when the sample and the bulk are scoured. Unfortunately, information on the shrinkage of an individual clip or lot is seldom available, since the manufacturer will customarily blend several clips or lots in preparation for processing, and thus lose the identity of the individual lot. As an alternative to the probably more ideal arrangement of obtaining information as to the shrinkage of an individual clip, tests were conducted in which comparison was made between a limited number of bags, processed separately, and of samples drawn from those bags. For the most part, the facilities of commercial scouring plants

were employed for determining the shrinkages of the bulk quantities, while the shrinkages of the samples were ascertained in the wool laboratory of the Agricultural Marketing Service under the usual testing methods. The comparisons are given in table 3, pages 13-15, inclusive.

In table 3, 104 comparisons of individual sample shrinkages with bulk shrinkages are shown. The extreme differences of individual sample shrinkages from the corresponding bulk shrinkages are -3.2 percent and +2.3 percent. Of the 104 comparisons made between individual sample shrinkages and bulk shrinkages, the differences in only 9 cases exceed 2 percent. This shows that an individual sample in 90 percent of the tests will indicate within 2 percent the shrinkage of the bulk.

In table 3, all but one of the larger quantities of wool were sampled in duplicate. When the average shrinkage of the duplicate samples from a given bulk is compared with the shrinkage of the bulk, the agreement is better than when individual sample shrinkages are compared with the shrinkage of the bulk. For this reason, duplicate samples on all clips are being taken and their average shrinkage used for purposes of comparison with the bulk shrinkage. Also in table 3, there are 49 comparisons shown between the average shrinkage of duplicate samples drawn from single bags and the bulk shrinkage of those bags. In these 49 comparisons, the extreme variations between the bulk shrinkages and the average sample shrinkages are -2.4 percent and + 1.6 percent, with an average variation of 0.7 percent. The greatest differences between the average shrinkage of samples applicable to 2 or more bags and the shrinkage of those bags are -1.9 percent and +1.2 percent, with an average variation of 0.5 percent. Quite encouraging is the fact that 95 percent of the differences between sample and bulk shrinkages were onl7 1.7 percent or less. That the average shrinkage of all samples is 59.1 percent, differing by only 0.1 percent from the average shrinkage of all entire bags of 59.2 percent, is another indication of the soundness of the sampling method being used.

SOME PERSONAL BIAS APPARENT IN SAMPLING

Random samples are intended to be entirely impartial, and attempts are made to keep the personal element out of the sampling. There is some question, however, as to whether or not personal bias has been entirely eliminated. In one Utah clip, for instance, one set of samples was consistently higher in shrinkage than the samples from the same wool drawn by another person. The same thing is noticed in connection with Wyoming yearling wool, where one set of samples was consistently higher in shrinkage than another. The only explanation that can be offered is that some samplers tend, subconsciously, to pick heavier wool than others. It is recognized that if sampling is to be confined to a hand method, reliable results will be attained only when complete impartiality on the part of the sampler is maintained.

This personal element is one which may be difficult to overcome completely as long as sampling remains an operation by hand. The development of a mechanical sampling device that would work well on domestic wool regardless of how it is packed, would take care of this problem, since by

placing the sampling upon a purely mechanical basis, all bias would be avoided. Although the human element has been demonstrated to be a disturbing factor, it yet has been possible 95 percent of the time to sample by hand limited amounts of wool of reasonably uniform grade and determine its shrinkage with an error of not more than 1.7 percent.

BAGS SAMPLED AT THE OPENED SEAMS

Previously in sampling one or more bags, the procedure was to open each bag and remove all the fleeces. The opening of the bags and the handling and repacking of the fleeces, however, involved a considerable expenditure of labor and time. In order to learn whether sampling could be simplified and speeded up, it was decided to open merely the seams of the bags and to take parts from those fleeces which could be reached through the opened seams. When we consider the dispatch with which sampling can be done in this manner, it appears that the operation is quite practical.

Naturally, the value of seam sampling will be determined by the results obtained from the samples so selected, and studies are now being conducted with a view to obtaining detailed information in this respect. One application of this method is recorded in the following experiments where a comparison is made of seam sample shrinkages with those found when all fleeces in the unit had been sampled, as well as with the entire lot.

Experiment:

Through the cooperation of an eastern manufacturer the opportunity was afforded for conducting shrinkage experiments on a large lot of Fine 12-months Texas wool. The facilities of both the mill laboratory and the Agricultural Marketing Service wool laboratory were employed in testing the samples, which were drawn according to several methods. The desired check on the results of the tests on the samples was obtained through the processing of the lot on completion of the sampling. The experiment was outlined as follows:

1. Main Lot
   1032 bags Fine, 12-months Texas wool of a total weight of 202,710 pounds, comprising 7 smaller lots that varied in size from 60 to 200 bags.

2. Major Processing Unit
   90 percent of mail lot, consisting of 929 bags, to be processed without prior testing.

3. Major Test Unit
   10 percent of lot, consisting of 103 bags, selected systematically by number and including a proportionate representation from each of the 7 lots composing the main lot of 1032 bags.

4. Sampling Unit
   13 bags, from a major test unit of 103 bags, comprising a representation of each of the 7 original lots. These 13 bags were selected according to whether their weight was near the average weight, as shown by invoice, on the assumption that bags of average weight would contain wool neither disproportionally heavy nor disproportionally light in shrinkage.

Two methods were employed in sampling the 13 bags constituting the sampling unit. First, a seam of each of these 13 bags was opened and the fleeces along the seam line were sampled according to the previously mentioned seam-sampling method. Each bag of the 13 was so sampled by a representative of the mill and a representative of the Agricultural Marketing Service. No attempt was made by the operators to exercise choice in the selection of wool going into the samples; on the contrary, personal judgment was eliminated so far as possible. In the seam-sampling of the 13 bags, only those fleeces exposed along the seam lines contributed to the composite sample.

At the conclusion of the seam-sampling, and in order that all the fleeces in each bag would be represented, the bags were opened and every fleece was individually sampled by the "random hand sample" method. Again samples were taken by representatives of both the mill and the Agricultural Marketing Service.

At the conclusion of the sampling operations, the 13 bags, less, of course, the amount of wool withdrawn as samples, were returned to the major test unit lot from which they had been taken. This lot of 103 bags was then processed as a unit by the mill. The mill's figures on the shrinkages of this lot afforded a valuable second processing check on the results obtained in the tests of the samples in the laboratories.

The samples selected by the manufacturer's representative were tested in the mill laboratory, while the samples of the Agricultural Marketing Service were tested in its laboratory. In order that results might be on the same basis, the tentative standards in connection with moisture, cleaned wool, etc., were adhered to. The detailed results of this experiment are given in table 4.

Table 4 - Bulk and sample shrinkages on 1,032 bags of Fine Texas wool

Portion Tested	Weight	Shrinkage
	Pounds	Percent
929 bags	182,769.0	61.09
103 bags	20,418.0	61.15
Random Sample, AMS (13 bags)	59.3	61.50
Random Sample, Mill Lab. (13 bags)	57.6	61.34
Seam Sample, AMS (13 bags)	25.1	60.00
Seam Sample, Mill Lab. (13 bags)	25.5	60.77

From the preceding results it appears that the 103 bags, or 10 percent, accurately represented the lot, and that all the samples drawn from the still smaller sublot of 13 bags also were well representative of the entire lot.

PRELIMINARY REPORT ON TEST OF 380 BAGS OF ORIGINAL WYOMING WOOL IN COOPERATION WITH MANUFACTURER

The lot under test was a single clip of original Wyoming wool totaling 380 bags. Because of the variability of the wool with respect to grade and shrinkage, slightly more than 10 percent, or 40 bags (spaced uniformly throughout the 380 bags), were set aside as a test unit. These 40 bags were divided into a 32-bag sublot and an 8-bag sublot. Following this, the seams of the 8 bags were opened, and duplicate samples were selected. One set of the samples was drawn by the manufacturer's representative and the other by the representative of the Agricultural Marketing Service. After the 8 bags had been sampled, the 32 remaining bags were sampled in the same manner. This procedure resulted in 2 sets of samples from the 8-bag unit and 2 sets from the 32-bag unit.

The shrinkage of the manufacturer's samples was determined at the mill, whereas the other samples were tested in the AMS wool laboratory. The agreement between the shrinkage of all samples is shown by the following tabulation of results:

Sample	Weight Pounds	Shrinkage Percent
USDA sample from 8 bags	22	66.5
USDA sample from 32 bags	60	67.0
Mill sample from 8 bags	25	65.5
Mill sample from 32 bags	48	66.5

The shrinkages given above are not only in good agreement with each other, but also with the shrinkage estimated for the lot. Comparison of these shrinkages with the actual shrinkage of the bulk will be possible on completion of the processing of the lot at the mill.

A COMPARISON OF THE SHRINKAGE OF BODY SORTS WITH THAT OF THE ENTIRE FLEECE

In cooperation with the Bureau of Animal Industry, the Agricultural Marketing Service conducted experiments to obtain information that would show with what degree of accuracy a particular part of a fleece indicates the shrinkage of the entire fleece. This project has been carried on for three seasons. The fleeces used in the experiments were taken from yearling ewes and from the same sheep each subsequent year. This experiment will be continued during 1941 and at a later date a report of the findings will be released.

SUMMARY

In making this study, the shrinkages of samples were compared with the shrinkages of the wool from which the samples were taken. The average shrinkage of two samples in most instances and three samples in others selected by the random method in 49 tests showed an extreme variation from the shrinkage of the entire unit under test of -2.4 percent and +1.6 percent. In 95 percent of these tests, the difference was 1.7 percent, or less. The simple average of all the samples differed by only -0.1 percent from the simple average shrinkages of all the lots tested. The closeness of this agreement indicates that random hand sampling, although still in the experimental stage, has potential commercial value.

A limited number of experiments, in which samples were confined to those selected at the opened seams of the bags, produced results that indicate that this procedure may be found to be practical.

The influence on shrinkage caused by the presence of tags in lots of fine and half-blood territory wool that have been prepared for market in a manner satisfactory to the trade will not result in serious error provided the sampling is correctly carried out.

It has been shown that uncontrolled laboratory procedure will result in shrinkages of questionable accuracy, and that standardization in test methods must proceed hand in hand with improvements in sampling technique.

Table 1 - Comparison of shrinkages exclusive and inclusive of offsorts 1/

Clip No.	Grade	Bulk Weight	Offsorts	Offsorts	SHRINKAGES Excluding Offsorts	SHRINKAGES Including Offsorts	Increase due to Offsorts
MONTANA WOOL		Pounds	Pounds	Percent	Percent	Percent	Percent
4007	Fine & 1/2 Blood	164	7	4	57.7	58.9	1.2
"	3/8 & 1/4 Blood	91	4.5	5	50.6	52.2	1.6
4008	Fine Ewes	676	16.25	2	58.4	59.6	1.2
"	Fine Yearlings	345	20	6	59.0	60.7	1.7
4009	Fine, 1/2 & 3/8 Blood	767	45.5	6	61.8	63.1	1.3
4010	Fine & 1/2 Blood	357	15.5	4	59.1	59.7	.6
4011	Fine, 1/2 & 3/8 Blood	260	5	2	49.7	51.6	1.9
4016	1/2 & 3/8 Blood	322	7	2	60.3	61.0	.7
"	1/2 Blood	303	6.5	2	62.5	63.5	1.0
4017	Fine Ewes	282	8.25	3	58.1	58.9	.8
"	Fine Yearlings	253	5	2	55.4	56.5	1.1
4018	1/2 & 3/8 Blood	285	9.1	3	56.7	58.4	1.7
4019	1/2 Blood	267	5.5	2	59.5	60.5	1.0
4020	1/2 & 3/8 Blood	239	7.5	3	50.3	51.4	1.1
"	Fine	259	7.0	3	52.8	53.8	1.0
"	1/2 & 3/8 Blood	237	4.5	2	49.0	50.1	1.1
4021	Fine & 1/2 Blood	285.5	3.8	1	58.9	59.3	.4
4022	Fine, 1/2 & 3/8 Blood	300	8.7	3	58.1	59.6	1.5
4023	1/2 & 3/8 Blood Ewes	269	4.6	2	52.8	54.4	1.6
"	1/2 & 3/8 Blood Yearlings	286	4.0	1	48.8	49.5	.7
4024	Fine, 1/2 & 3/8 Blood	285	5.5	2	55.5	56.5	1.0
Average				2.8			1.2

1/ Included in offsorts are low, stained, tags, paint clips, string, and sorting loss.

Table 3 - Comparison of random sample shrinkages with bulk shrinkages

Clip No.	Grade	Bulk Scoured at	Average Sample Weight	Weight Bulk	SHRINKAGES: Sample No. 1	Sample No. 2	Sample No. 3	Average of Samples	Bulk	Difference between samples & bulk
			Pounds	Pounds	Percent	Percent	Percent	Percent	Percent	Percent
UTAH WOOL										
4002	Fine	Mill	33	681	63.8	65.7		64.8	65.9	-1.1
"	1/2 Blood	Mill	12	346	60.3	62.6		61.5	62.2	-0.7
"	3/8 Blood	Mill	11	294	59.4	61.1		60.3	60.9	-0.6
"	All Grades	Mill	56	1321	62.4	64.4	62.6 1/	63.4	64.4	-1.0
"	Fine	AMS	19	224	63.9	64.2		64.1	64.1	0.0
"	1/2 Blood	AMS	19	224	59.4	61.2		60.3	61.7	-1.4
"	3/8 Blood	AMS	19	224	59.0	60.2		59.6	59.5	+0.1
"	All Grades	AMS	57	672	62.1	63.0		62.6	63.0	-0.4
WYOMING WOOL										
4001	Fine	Mill	18	327	65.2	65.9		65.6	65.1	+0.5
"	1/2 Blood	Mill	14	309	59.6	62.0		60.8	60.2	+0.6
"	3/8 Blood	Mill	15	314	59.2	60.0		59.6	59.4	+0.2
"	1/4 Blood	Mill	14	340	56.1	56.2		56.2	55.5	+0.7
"	All Grades	Mill	61	1290	60.4	61.6		61.0	60.6	+0.4
"	Fine	AMS	19	257	66.5	66.2		66.4	66.1	+0.3
"	1/2 Blood	AMS	14	257	61.2	60.8		61.0	61.0	0.0
"	3/8 Blood	AMS	15	257	58.9	60.8		59.9	60.0	-0.1
"	1/4 Blood	AMS			56.2 2/	56.2 2/		56.2 2/	56.2 2/	
"	All Grades	AMS	48	771	61.2	61.5		61.4	61.3	+0.1
"	Fine Yearlings	AMS	5	69	65.3	63.2		64.3	64.2	+0.1
"	1/2 Blood Yearlings	AMS	10	250	65.2	61.7		63.5	63.0	+0.5
"	3/8 Blood Yearlings	AMS	6	241	58.8	55.7		57.3	58.8	-1.5
"	1/4 Blood Yearlings	AMS	4	62	52.9	51.9		52.4	51.8	+0.6
"	All Grades	AMS	25	622	61.7	59.0		60.4	60.5	-0.1
4002	Fine & 1/2 Blood	Mill	17	401	65.5			65.5	67.2	-1.7

1/ Random samples throughout clip.

2/ The average 1/4 blood random sample shrinkage from the preceding test.

Table 3 - Comparison of random sample shrinkages with bulk shrinkages--Continued

Clip No.	Grade	Bulk scoured at	Average sample weight	Weight bulk	Sample No. 1	Sample No. 2	Sample No. 3	Average of samples	Bulk	Difference between samples & bulk
			Pounds	Pounds	Percent	Percent	Percent	Percent	Percent	Percent
WYOMING WOOL--Continued										
4004	Fine & 1/2 Blood	AMS	12	337	67.7	66.8		67.3	66.6	+0.7
4005	Fine & 1/2 Bld. Ewes	Mill	17	321	67.8	68.2		68.0	68.6	-0.6
"	Fine & 1/2 Bld. Yrlgs.	Mill	18	368	65.9	66.5		66.2	66.6	-0.4
"	All Grades	Mill	35	689	66.9	67.4		67.1	67.6	-0.5
4006	Fine & 1/2 Blood	AMS	12	328	70.4	68.6		69.5	69.0	+0.5
MONTANA WOOL										
4007	Fine & 1/2 Blood	Mill	8	180	57.2	57.2		57.2	58.9	-1.7
"	3/8 & 1/4 Blood	Mill	4	100	49.0	50.5		49.8	52.2	-2.4
"	All Grades	Mill	12	280	54.7	55.1		54.9	56.8	-1.9
4008	Ewes	Mill	15	676	60.7	61.1		60.9	59.6	+1.3
"	Yearlings	Mill	10	345	61.8	61.6		61.7	60.7	+1.0
"	All Grades	Mill	25	1021	61.1	61.3		61.2	60.0	+1.2
4009	Fine, 1/2 & 3/8 Bld.	Mill	17	801	62.6	62.3		62.5	63.1	-0.6
4010	Fine & 1/2 Blood	Mill	15	386	58.8	59.3		59.1	59.7	-0.6
4011	Fine, 1/2 & 3/8 Blood	Mill	10	271	50.5	53.3	51.5	51.8	51.6	+0.2
4016	1/2 & 3/8 Blood	Mill	10	342	60.7	60.4		60.6	61.0	-0.4
"	1/2 Blood	Mill	9	321	62.6	63.6		63.1	63.5	-0.4
"	All Grades	Mill	19	663	61.7	62.0		61.9	62.3	-0.4
4017	Fine Ewes	Mill	14	281	60.1	59.7		59.9	58.9	+1.0
"	Fine Yearlings	Mill	14	310	56.7	56.3		56.5	56.5	0.0
"	All Grades	Mill	28	591	58.4	58.0		58.2	57.7	+0.5

Table 3 - Comparison of random sample shrinkages with bulk shrinkages--Continued

Clip No.	Grade	Bulk scoured at	Average sample weight	Weight bulk	SHRINKAGES Sample No. 1	Sample No. 2	Sample No. 3	Average of samples	Bulk	Difference between samples & bulk
			Pounds	Pounds	Percent	Percent	Percent	Percent	Percent	Percent
MONTANA WOOL--Continued										
4018	1/2 & 3/8 Blood	Mill	12	321	58.1	58.3	58.6	58.3	58.4	-0.1
4019	1/2 Blood	Mill	10	267	58.5	59.9	60.0	59.5	60.5	-1.0
4020	1/2 & 3/8 Blood	Mill	14	268	51.3	51.5		51.4	51.4	0.0
"	Fine	Mill	12	283	53.0	53.6		53.3	53.8	-0.5
"	1/2 & 3/8 Blood	Mill	14	265	50.2	49.8		50.0	50.1	-0.1
"	All Grades	Mill	40	816	51.5	51.6		51.6	51.8	-0.2
4021	Fine & 1/2 Blood	Mill	11	307	60.0	60.1		60.1	59.3	+0.8
4022	Fine,1/2 & 3/8 Blood	Mill	12	327	58.4	59.6	58.6	58.9	59.6	-0.7
4023	1/2 & 3/8 Blood Ewes	Mill	10	289	51.7	52.0	52.3	52.0	54.4	-2.4
"	1/2 & 3/8 Bld. Yrlgs.	Mill	11	312	50.3	50.0	50.5	50.3	49.5	+0.8
"	All Grades	Mill	21	601	51.0	51.0	51.4	51.2	52.0	-0.8
4024	Fine, 1/2 & 3/8 Blood	Mill	8	301	57.4	57.9		57.7	56.5	+1.2
TEXAS WOOL										
	12 Mo. Fine	Mill	58	20418	61.5	61.34		61.42	61.15	+0.27
IDAHO WOOL										
	3/8 & 1/4 Blood	AMS	7	301	53.7	53.5	53.0	53.4	53.4	0.0
	3/8 & 1/4 Blood	AMS	7	301	52.3	54.7		53.5	53.4	+0.1
	3/8 & 1/4 Blood	AMS	9	300	53.0	53.1		53.1	52.6	+0.5
	1/4 Blood	AMS	9	313	49.0	47.8		48.4	48.0	+0.4
	Fine & 1/2 Blood	AMS	9	332	62.0	60.6		61.3	59.7	+1.6
Unweighted averages, all samples and bags								59.1	59.2	-0.1

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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Administration

REPORT OF PROGRESS IN WOOL SHRINKAGE RESEARCH DURING 1941

By Warner M. Buck, Specialist in Marketing Wool
and George C. LeCompte, Associate Wool Technologist

INTRODUCTION

At the insistent demand of wool producers, development of a quick method of sampling grease wool to determine its shrinkage was undertaken in 1937 by the Department of Agriculture through its wool research laboratory in the Agricultural Marketing Administration. Work has been carried on continuously since that time in cooperation with the Bureau of Animal Industry, laboratories of colleges, universities, State experiment stations of Colorado, Montana, New Mexico, Texas, Utah, and Wyoming, and various woolen mills. Reports have been issued each year showing the progress of the research. 1/

By 1940, the possibilities of developing a satisfactory method of test became apparent. That year comparisons were made of the shrinkages of 49 separate quantities of wool and the average shrinkage of two samples in most instances and three in others selected by the random method showed extreme differences from the entire unit under test of -2.4 percent and +1.6 percent. In 95 percent of these tests the difference was 1.7 percent or less. This research has taken on new and added significance during the past year, in view of the importance of wool as a constituent of the clothing of our armed forces.

METHODS OF APPROACH

As in previous years, the principal aim during 1941 has been to establish the accuracy of the sampling methods by obtaining as many comparisons as possible between accurate bulk shrinkages and corresponding sample shrinkages.

During the past year, attention has been paid to the problem of how variable were the domestic wools sampled, and how closely samples drawn from wools of such demonstrated variability could be expected to represent the bulk. The results obtained indicated that with even the most variable Territory wools, sampling remained a practical matter. The information obtained also indicated clearly the minimum amount of sampling necessary to represent Territory wools with reasonable accuracy.

1/ Copies of these reports, for 1938, 1939, and 1940, may be obtained from The Marketing Reports Division, Agricultural Marketing Administration, Washington, D. C.

Many efforts have been made to devise a satisfactory mechanical sampling device for use on Territory wools.

Progress has been made in adapting the laboratory procedure to the testing of smaller samples than heretofore. Half-pound subsamples drawn from thoroughly blended and homogenized wool were scoured in small tubs with excellent results. Changes in apparatus are also being made which should result in further progress in blending.

RANDOM HAND SEAM SAMPLING

The method followed in selecting samples on which reports are made herein may be designated as random hand seam sampling. This method of samplin calls for pulling the seams of the bag to be sampled, and taking a number of handfuls of wool, weighing possibly 1/20 of a pound each, at regular intervals along the opened seam. Efforts are made to draw handfuls from well under the surface of the wool as well as from the immediate surface.

The studies of the variability of Territory wools indicate that in some cases the variability may attain a value as high as 7.2 percent shrinkage. (This figure of 7.2 percent shrinkage represents the standard deviation with respect to single handfuls of the most variable Territory wools.) If 200 handfuls are drawn, it is evident that the standard error of the average shrinkage of that number of handfuls will be in the neighborhood of 0.5 percent. This indicated that the limits of uncertainty for such samples for a probability of 0.95 is $\pm$1.0 percent. The unavoidable errors in all field and laberatory weighings and processes operate to raise these expected limits of error to $\pm$1.5 percent for a probability of 0.95.

The fact that the random hand seam sampling method tends to restrict the sampler to definite locations in the bags sampled has the effect of decreasing the personal bias exhibited by the sampler. Experiments carried out by means of the random hand seam sampling method seem to indicate little personal bias; completely inexperienced samplers, however, will tend to draw samples that are low in shrinkage. It appears advisable therefore, that samplers should obtain some experience in the method before putting it into practice.

RESULTS

During the past year, it has been impossible to obtain determinations of shrinkages on entire clips and lots. Bulk shrinkages have been obtained on small lots varying in size from 1 bag up to 5 bags. In arriving at a decision as to how accurate sample shrinkages might be, they have been compared with the bulk shrinkages found for the entire bags from which the samples were drawn. It is desirable to stress that in such a procedure, good agreement will be found only if both the findings for sample shrinkages and those for the entire bag are accurate, and it appears quite possible in making such comparisons that the determinations for the entire bag shrinkages were in error, rather than those for the samples.

In the program of the Agricultural Marketing Administration, it has been necessary to have entire bags scoured by commission wool scourers or to cooperate in experiments involving such work. During 1941, commission scourers processed some 40,000 pounds of wool which had been sampled by the Agricultural Marketing Administration. The year's work necessitated more than 900 individual shrinkage determinations requiring the scouring of some 5,900 pounds of wool in the AMA laboratory.

The experiments carried on during the past year are classified into seven groups:

1. Experiments in which sample shrinkage findings were compared with those for the entire bag as made in the laboratory of the Agricultural Marketing Administration. These entire-bag shrinkage determinations had a definite and ascertainable degree of accuracy.

2. Experiments in which the entire-bag shrinkages were determined by a commercial scourer. Here, there was no way of ascertaining the accuracy of the results as obtained by the commercial scourer, except by comparing them with the AMA sample shrinkage findings.

3. In a large number of experiments in which the AMA laboratory cooperated with the wool scouring plant of the Texas Agricultural and Mechanical College, no check as to the accuracy of the sampling was possible except by comparing one sample shrinkage as determined by AMA with another sample shrinkage as determined by the Texas laboratory.

4. Tests on farm flock wools in which commercially determined shrinkages, whose accuracy could not be ascertained, were used for comparison with AMA sample findings.

5. Experiments with mechanical sampling.

6. Experiments in blending wool samples.

7. Experiments to establish correct scouring temperatures.

Results obtained during 1941 are discussed below under the respective headings.

1. Comparisons between sample shrinkage determinations for samples and for the entire bag, in which the latter were made in the AMA laboratory and had a definite and ascertainable accuracy. A total of seven tests was run involving 37 individual sample shrinkages. The extreme differences found for the samples from the entire bag shrinkages were +1.2 percent and -1.3 percent. In these 37 comparisons, 31 sample shrinkages differed by less than 1 percent from the shrinkage of the corresponding entire bag. The simple average of all sample shrinkages was 56.2 percent, and the simple average of all entire bag shrinkages was 56.0 percent, the difference between the two being only 0.2 percent.

2. Comparisons between sample shrinkages and entire bag shrinkages in which the latter were determined by commercial scourer. In these tests the accuracy of the entire bag shrinkages could not be demonstrated. The results under this classification were all obtained in one large experiment involving commercial tests on four 5-bag lots and two 1-bag lots of Territory wool. On the 5-bag lots, samples were drawn not only by the random hand seam sampling method but also by the Treasury Department's coring device. The results are shown in Table 1.

Table 1 - Sample and entire bag shrinkages as found for 5-bag lots of domestic wools

Kind of wool	SHRINKAGES				
				Dif. from entire lot	
	A.M.A. Sample	Treasury Department sample	Commercially determined entire lot	A.M.A. Sample	Treasury Department sample
	Percent	Percent	Percent	Percent	Percent
Rambouillet	58.1	57.5	57.7	+0.4	-0.2
Targhee	53.0	53.7	52.9	+0.1	+0.8
Corriedale	49.3	50.2	48.7	+0.6	+1.5
Columbia	47.0	47.6	46.8	+0.2	+0.8
Average	51.9	52.3	51.5	+0.3	+0.7

In the preceding table, the shrinkages as found by AMA are quite close to those found by the mill for the entire bag. Each AMA shrinkage above represents the average of 10 individual sample shrinkages. It was also found in comparing the 40 individual AMA sample shrinkages with the entire bag shrinkages as determined by the mill, the extreme differences are +1.5 percent and -0.7 percent. Only four of the 40 shrinkage determinations differed as much as 1 percent, or more, and none exceeded 1.5 percent. The above results indicate very strongly that the random hand seam sampling method is quite reliable within the limits of uncertainty of ±1.5 percent.

In addition to the above tests on 5-bag lots, there were experiments on two 1-bag lots, Here, on one bag of long staple Rambouillet wool, the commercially determined entire bag shrinkage was 56.7 percent, while the corresponding AMA sample shrinkages were 55.2 percent, 55.4 percent, and 55.4 percent. That all three of the sample shrinkages should be lower by the amounts indicated than the shrinkage determined by the mill appeared very unusual, since the results on the 40 samples in the preceding 5-bag tests had indicated the maximum error of the sampling method to be 1.5 percent, with sample shrinkages tending to be higher by approximately 0.3 percent rather than to be lower than those determined by the mill.

On a single bag of short staple Rambouillet wool, the commercially determined entire-bag shrinkage was 60.7 percent, with corresponding AMA sample shrinkages of 58.3 percent, 57.5 percent, and 57.9 percent. The indicated differences were -2.4 percent, -3.2 percent, and -2.8 percent. These differences exceeded all expected limits.

The results on these two 1-bag tests indicated that either the two commercially determined entire-bag shrinkages or the six sample shrinkages were in error. In view of the fact that previous results had demonstrated the AMA sampling method to be reliable and that a sample drawn from one bag should be much more representative than the same size sample drawn from five bags, while commercial determinations on single bags might be unreliable, it was concluded that the commercial shrinkage determinations on the two single bag tests had been in error. Although it is evident that the quantities of wool involved may be too small to permit of accurate commercial shrinkage determinations, in these two tests at least the evidence is that the sample shrinkage determinations are more reliable than the commercially determined shrinkages on the entire lots in question.

3. Results in which no entire-bag shrinkages were obtained but duplicate sample shrinkages were obtained in cooperating laboratories. In these experiments it was possible to obtain some 70 comparisons on samples drawn from Texas clips. One of a pair of duplicate samples was scoured at the wool scouring plant of the Texas Agricultural and Mechanical College, while the other was scoured in the AMA wool scouring laboratory. In these tests, it was found that the only possible indication of accuracy of the samples lies in an inspection of the differences between the paired sample shrinkages. It is evident that if samples may be in error at times by as much as 1.5 percent, occasional duplicate samples must exhibit differences of as much as 3.0 percent, since one sample might be in error by +1.5 percent, while the other might be in error by -1.5 percent. On the 70 comparisons in these tests, we found the extreme difference to be 3.1 percent. In all other comparisons, the differences were 2.9 percent, or less; 41 of the differences were less than 1.0 percent; 21 were less than 2.0 percent; 8 ranged from 2.1 to 2.9 percent, and as stated before, the extreme deviation was 3.1 percent. Here, we find no evidence to indicate definitely that the random hand seam sampling method will give rise to errors exceeding 1.6 percent.

4. Tests on farm flock wools. It was possible for the AMA to cooperate in these experiments due to the kindness of a cooperative wool marketing association. The lots involved were Minnesota wools, extremely taggy and non-uniform in type. The wools sampled consisted of 5-bag lots. In addition to being non-uniform, the wool in most of the lots was quite damp near the interior of the bags, while it was more or less dry near the exterior. In some cases, this dampness had been sufficient to create a noticeable odor of mildew. Owing to the non-uniformity of these Minnesota wools, the results were not as satisfactory as those previously described for the better prepared Territory wools. Considering, however, the uneven nature of the farm flock wools sampled and the fact that these were the first experiments with this type of wool, the results obtained are promising. In the 9 tests run on this type of wool, differences of the samples from the commercially determined entire bag shrinkages were found to be as follows: -1.2 percent, -2.5 percent, -0.6 percent, -1.0 percent, +1.2 percent, +1.1 percent, +1.7 percent, +0.5 percent and +2.0 percent.

5. Experiments dealing with mechanical sampling. Efforts have been made to get away from the personal element involved in hand sampling by using mechanical sampling devices. Many of these have been constructed, tried out, and rejected. Some were rejected because of the difficulty or even impossibility of drawing samples with them.

Others drew samples easily but gave inaccurate results. It is noteworthy that these experiments denoted that a mechanical sampling tool may have a high degree of mechanical bias. Depending upon the design of the tool, samples drawn may have a bias towards high shrinkages or towards low shrinkages. Tools constructed in the form of harpoons apparently tend to draw from the bags the longer staples having lower shrinkages, and in drawing the samples from the bags by this means, there is a tendency for the loose dirt to be stripped from the wool. The net result is a bias towards low shrinkages which may amount to as much as from 3 to 4 percent.

Boring devices, when used on loosely packed wools, have a bias towards high shrinkages, which may amount to as much as 2 percent. It is felt, however, that with suitably compressed wools, the bias of boring devices can be entirely eliminated.

Some simple devices for sampling which are pushed directly into the bag have been shown to be free from bias, although the drawing of a sample with them is more or less arduous.

The experiments have shown that samples with no bias can be drawn by mechanical means and that the variability of such samples in some cases is less than one-half that of hand-drawn samples from the same wool. It appears that very shortly it will be possible to show that mechanical sampling of Territory wools is practicable and statistically sound.

6. Experiments in blending wool samples. There are many advantages inherent in obtaining shrinkage results from small subsamples rather than from the larger samples of 20 or 30 pounds. The process is quicker, cheaper, affords the opportunity for better control, and it is always possible to go back and check results. On the other hand, a loss of precision is entailed with the subsample unless the larger sample from which it was drawn has been properly blended and homogenized. Experiments are under way to improve upon the results obtained with the regular Wilson-type duster in blending and homogenizing large wool samples. Introduction of an extra series of fixed teeth into the Wilson duster helps considerably in obtaining better blending. Two other devices are being experimented with, however, which appear to produce far better blending action than any simple modification of the Wilson duster. Incomplete results obtained from these devices so far, indicate that the variability of blended samples is less than one-half that of samples processed in the Wilson duster. As stated before, this work is still in the experimental stage, and will later be reported upon more fully.

7. Experiments to establish correct scouring temperatures. Although in the past it has been generally believed that scouring temperatures of from 120 to 125 degrees F. were the best to use, it was felt advisable to determine this more definitely. Scouring experiments, run at temperatures of from 80 degrees F. to 180 degrees F. indicated that there was a progressive increase in the damage incurred by samples and a progressive decrease in yield from samples as the scouring temperatures increased. Samples scoured at 125 degrees F. exhibited minimum contents of residual impurities. Temperatures in excess of 125 degrees F. had relatively slight effect in decreasing the yield of pure wool. On the other hand, when temperatures below 120 degrees F. were applied, the samples exhibited excessively high residual impurities.

The tests showed that samples scoured at 125 degrees F. would yield only about 0.20 percent less clean wool than if scoured at the impracticably low temperature of 80 degrees F. This lowering of yield of only 0.20 percent was considered negligible. The conclusion was reached that 125 degrees F. was the best temperature to use in scouring wool, for purposes of laboratory shrinkage determination.

SUMMARY

1. In 37 comparisons with bulk shrinkages of definite and ascertainable accuracy, random hand seam samples showed extreme differences of +1.2 percent and -1.3 percent. In 31 of these tests, the differences were less than 1.0 percent. The average sample shrinkage was higher than the average for the entire bag by only 0.2 percent.

2. In 40 comparisons with commercially determined shrinkages on 5-bag lots of Territory wool, the extreme differences found were +1.5 percent and--0.7 percent. Thirty-six of these 40 differences were less than 1.0 percent. The average sample shrinkage was higher than the average entire lot shrinkage by only 0.3 percent.

3. In comparing commercially determined shrinkages for single bags, the differences amounted to as much as 3.2 percent. After considering all points that appear to be pertinent to these tests, it was necessary to conclude that the commercially determined shrinkages on these single bag lots were in error.

4. In an interlaboratory test conducted by the Texas Agricultural and Mechanical Experiment Station, comparisons between the shrinkages of 70 duplicate samples showed the extreme differences between the paired samples to be 3.1 percent. In 41 of these 70 comparisons, the differences were less than 1.0 percent. In these experiments there was no evidence to indicate definitely that any random hand seam sample was in error by more than 1.6 percent.

5. In nine comparisons with commercially determined shrinkages on 5-bag lots of farm flock wools, the extreme differences were -2.5 percent and +2.0 percent. These differences are perhaps too large, but in view of the extreme variability of the wools tested and the fact that these are the first experiments run on such wools, the results are considered to be promising.

6. Statistical investigations have indicated that even the most variable Territory wools can be sampled with a sampling error of 1.0 percent and a probability of 0.95.

7. Results during the past year indicate that it is possible to sample Territory wools by the random hand seam sampling method and arrive at a shrinkage accurate within $\pm$1.5 percent and a probability of 0.95.

8. Mechanical sampling devices have been developed and experiments made with them. Indications are that mechanical sampling of Territory wool is practicable and statistically sound.

9. Improved blending devices have been developed for use in the sub-sampling of samples of wool. The variability of samples blended by means of these new devices is less than 1/2 that of samples blended by means of a Wilson type duster.

10. Experiments have borne out and more clearly demonstrated previous findings that 125 degrees F. is the most suitable temperature at which to scour wool.

11. In the light of information gained from numerous experiments it seems at the present time highly likely that a method of test having the possibilities of great value to wool growers will eventually be developed.

July, 1942

UNITED STATES DEPARTMENT OF AGRICULTURE
Food Distribution Administration

REPORT OF PROGRESS IN WOOL SHRINKAGE RESEARCH DURING 1942

(Shrinkage Determination by Means of Core Sampling)

By James M. Coon, Principal Marketing Specialist
Warner M. Buck, Senior Marketing Specialist, and
George C. LeCompte, Associate Wool Technologist

INTRODUCTION

Methods of determining wool shrinkage have been the subject of research by the U. S. Department of Agriculture for several years. This is a report on the work done in 1942. The purpose of the entire investigation has been to find a reliable, objective way of determining the shrinkage of a wool clip from a representative sample. Cooperating agencies, in addition to the U. S. Department of Agriculture, have been laboratories of colleges, universities, State experiment stations of Colorado, Montana, New Mexico, Texas, Utah, and Wyoming, and various woolen mills.

In 1941 Wollner and Tanner 1/ reported upon a method for determining the clean wool content of imported wools. In their method, baled foreign wools were sampled by means of a coring device. These baled wools were found to have a standard deviation with respect to the shrinkage of individual cores of as much as 2.5 percent. The expected limits of error for samples composed of 100 cores drawn from such wools were approximately ±0.5 percent for a probability of 0.95.

In the report for 1941 covering progress in the research here under discussion, Buck and LeCompte 2/ describe the seam sampling method as applied to domestic wool in the wool laboratory of the Food Distribution Administration. The seams of bags were opened and handfuls drawn at random from the wool exposed under the open seams. Results indicated that samples composed of 200 handfuls should render results accurate to ±1.5 percent for a probability of 0.95. In order to reduce personal bias, however, training in the hand sampling method appears to be necessary. For this reason it was thought advisable to experiment with the core sampling of domestic wool.

1/Wollner, H. J., and Tanner, L., Ind. and Eng. Chem. 13, 883, (1941)

2/Buck and LeCompte, Report of Progress in Wool Shrinkage Research during 1941, U. S. Department of Agriculture, 1942.

EXPERIMENTS WITH CORE SAMPLING

The wool experimented with consisted of bagged and baled domestic wool. Domestic wool in the form of fleeces (generally weighing from 6 to 10 pounds) are packed in bags 6 to 7½ feet in length. The fleeces are highly variable within themselves with respect to shrinkage and also exhibit great variation from one another. The baled wools used in this experiment, likewise, consisted of fleeces and these were compressed to a density of from 16 to 24 pounds per cubic foot.

Preliminary experiments had been conducted upon bagged domestic wool with mechanical sampling devices, including a 1¼ inch diameter coring tube, various instruments similar to harpoons, and a projection core cutting device. It was found that the projection core cutting device required too much physical exertion in sampling, that the harpoons had a bias toward low shrinkages, and that the narrow coring tube had a bias toward high shrinkages. Work was continued with the coring tube until eventually it was found that mechanical bias could be eliminated by compressing the wool before it was cored and by using a coring tube 2 inches in diameter.

The bags were first placed in a press consisting of a wooden base and levers. Pressure was exerted upon them until it was estimated they had a density of some 16 pounds per cubic foot. Each bag was sampled in the compressed region. Several investigations were made upon the variability of domestic wool including wools from Utah, Wyoming, Idaho, and Montana. In these investigations a series of individual cores were drawn, packed separately, and individual determinations of shrinkage run for them.

In order to establish definitely by actual experiment what accuracy could be expected from the core sampling method on domestic wools, three extensive experiments were conducted. In the most precise and decisive of these experiments a total of 16 bags of domestic wool were core sampled under pressure in the wool research laboratories of the Food Distribution Administration. The shrinkage of the remainder of the entire bags was determined in the laboratories by a carefully controlled dusting, blending, and subsampling procedure, so that it is possible to claim an accuracy for these entire bag shrinkages of ± 0.4 percent. In another experiment 145 bags of Idaho wool were core sampled in the plant of a commission wool scouring concern. Unfortunately, it was impossible to use a press in the sampling of these bags. The remainder of the bags were scoured and the shrinkage determined at the commission wool scouring concern. In the third experiment, 61 bales of Montana wool were sampled with the coring device, the remaining portions of the bales being scoured and the shrinkage determined at a commission wool scouring concern. In all cases the entire bag shrinkages reported include everything contained within the original wool bag or bale. Thus these shrinkages include not only the bulk sorts but also the offsorts

such as tags, stained, low and paint. The scoured weights upon which the shrinkages were calculated were based on 12 percent moisture and a 0.0 percent to 0.5 percent content of impurities removable by rescouring.

RESULTS

Table 1 records the findings upon the variability with respect to the shrinkage of individual cores of various domestic wools. It will be noted that the highest variability found was 4.03 percent on wool from a Wyoming clip. Since it is quite possible that any domestic clip sampled will have a variability this high, it seems desirable to use this standard deviation of 4.03 percent as a basis in estimating the accuracy that could be expected from the core sampling method on domestic wools.

Table 1 also records the expected limits of error for a probability of 0.95 for samples composed of the indicated number of cores. It will be noted that samples composed of 100 cores have maximum estimated limits of error of only ±0.8 percent. This is accurate enough to be of real value to the wool industry and yet samples composed of 100 cores do not require an impractical amount of labor in the actual sampling.

In table 2 comparisons are given between core sample shrinkages and the shrinkages of the entire bags from which these samples had been drawn. This table also shows the number of cores of which the samples were composed and the expected limits of error. It will be noticed that there are a total of 16 comparisons possible. The extreme errors shown are ±1.0 percent and -1.1 percent. All these differences are within the expected limits of error. These experiments were the most decisive and conclusive of those run, in that the entire bag shrinkages had a high degree of reliability. The good agreement between sample and entire bag shrinkages attests to the essential soundness of the core sampling method.

In scouring the core samples from the 9 bags of Idaho wool noted in table 2, the experiments were conducted in such a manner that it was possible to obtain a series of average core sample shrinkages that could be compared directly to the average shrinkage of the 9 bags. In table 3, 10 such comparisons are made in which the core sample shrinkages represent the average shrinkage of 45 cores. In addition there are 10 comparisons in which core sample shrinkages represent the average of 90 cores. On the samples composed of 45 cores, the extreme differences shown are +1.1 percent and -1.8 percent, and on the samples composed of 90 cores, the extreme differences are +0.8 percent and -1.0 percent. Of the 20 comparisons made in only two instances does the demonstrated difference exceed the expected limits of error. These 20 comparisons give further evidence of the accuracy of the core sampling method.

Table 4 shows the results between core sample shrinkages drawn from various lots of bagged Idaho wools and the corresponding entire bag shrinkages as determined in the plant of a commission wool scouring concern. It will be noticed that the extreme differences between the core sample shrinkages and the entire bag lot shrinkages are +2.4 percent and -1.5 percent. These differences in several cases exceed the expected limits of error. The reasons for these large differences can be attributed to several factors. Most of the lots sampled were quite small and consequently the commercially determined shrinkages were expected to be more or less inaccurate. Due to the small size of the lots the number of cores per sample were restricted. The final and most serious factor, the lack of a press, contributed to inaccuracy in sampling. On the other hand, the close agreement between the average sample shrinkage and the average bag shrinkage on these tests shows that accurate results are possible if the lots tested are reasonably large and if sufficient cores are drawn.

In table 5 comparisons are made between core sample shrinkages and the corresponding entire lot shrinkages on baled wools as determined by a commission wool scourer. On small lots, composed of from 2 to 4 bales, the extreme differences shown are +0.2 percent and -1.5 percent. On the two larger lots, composed of 32 and 29 bales respectively, the indicated differences are -0.5 percent and -0.1 percent. In all these cases the experimentally determined differences are within the statistically expected limits of error.

SUMMARY

1. The highest variability found on domestic wools with respect to the shrinkage of individual cores was 4.03 percent on a bagged Wyoming wool. The extensive tests run indicated that samples composed of 100 cores drawn from large lots of compressed territory wools should be reliable within $\pm$0.8 percent for a probability of 0.95. Thus, in 5 comparisons between commercially determined entire lot shrinkages and average core sample shrinkages determined in the wool laboratory of the Food Distribution Administration in which the samples contained from 133 to 313 cores, the extreme variations were +0.5 percent and -0.5 percent.

2. On small lots, in 9 comparisons between commercially determined 2 to 4 bale lot shrinkages and core sample shrinkages in which the samples contained 24 to 30 cores, the extreme differences were +0.2 percent and -1.5 percent. Similarly, in 14 comparisons between the shrinkages of single bags scoured by the U. S. Department of Agriculture wool research laboratory and samples composed of 50 cores, the extreme differences were +1.0 percent and -1.1 percent. On these last tests, still another 20 comparisons on average samples composed of 45 cores and 90 cores showed extreme variations of +1.1 percent and -1.8 percent. Indications were that samples should contain at least 100 cores.

3. In tests on bagged wools consisting of 4 to 37 bags, core samples containing 15 to 74 cores showed extreme variations of +2.4 percent and -1.5 percent. As might be expected, the higher variations tended to occur in samples containing the least number of cores. These bags were not compressed prior to sampling. The relatively high variations in these tests were caused by (a) lack of compression on the bags during sampling; (b) the small sizes of the lots given commercial tests; (c) the restricted number of cores that would be drawn from the small lots under test.

NOTE: We wish to acknowledge the assistance given by Dr. R. T. Clark and Mr. Curtis Hughes of Montana State College in the experiments on Montana wools.

May, 1943

Table 1.-Standard deviations and limits of error for core samples drawn from domestic wool

Wool	Standard deviation single cores (Percent)	Limits of error (probability of 0.95) for samples composed of: 25 Cores (Percent)	50 Cores (Percent)	100 Cores (Percent)	200 Cores (Percent)
Montana Clip 1	3.27	±1.38	±0.93	±0.69	±0.49
Montana Clip 2	2.81	±1.17	±0.81	±0.59	±0.42
Montana Clip 3	2.76	±1.11	±0.79	±0.56	±0.40
Wyoming Clip 1	4.03	±1.61	±1.14	±0.80	±0.57

Table 2.-Comparison of shrinkages of core samples with shrinkages of entire bags of wool
(Entire bags scoured by U. S. Department of Agriculture)

Type wool	Bag No.	Cores (Number)	Entire bag shrinkage (Percent)	Core sample shrinkage (Percent)	Difference (Percent)	Limits of error (P.=0.95) (Percent)
Idaho	8	50	53.0	53.6	+0.6	±1.14
"	24	50	40.6	39.5	-1.1	±1.14
"	36	50	42.4	42.7	+0.3	±1.14
"	43	50	52.2	53.2	+1.0	±1.14
"	71	50	44.3	44.4	+0.1	±1.14
"	75	50	52.6	51.8	-0.8	±1.14
"	84	50	52.9	53.1	+0.2	±1.14
"	93	50	49.9	49.8	-0.1	±1.14
"	134	50	48.7	49.7	+1.0	±1.14
Idaho	9 bags	450	48.5	48.6	+0.1	±0.38
Utah	5 bags	25	60.4	60.9	+0.5	±1.60
"	5 "	25	60.4	60.8	+0.4	±1.60
Utah	5 bag aver.	50	60.4	60.9	+0.5	±1.14
Wyoming	396	50	68.1	67.8	-0.3	±1.14
"	408	50	69.1	70.0	+0.9	±1.14
Wyoming	2 bag aver.	100	68.6	68.9	+0.3	±0.8

Table 3.-Comparison of average shrinkage of core samples, with average shrinkages of entire bags, of Idaho wool
(Entire bags scoured by U. S. Department of Agriculture)

Sample average number	Average sample shrinkage (Percent)	Average entire bag shrinkage (Percent)	Cores in sample (Number)	Limits of error (P. = 0.95) (Percent)	Actual difference (Percent)
1	48.2	48.5	45	±1.2	-0.3
2	47.9	48.5	45	±1.2	-0.6
3	48.3	48.5	45	±1.2	-0.2
4	49.6	48.5	45	±1.2	+1.1
5	48.0	48.5	45	±1.2	-0.5
6	48.6	48.5	45	±1.2	+0.1
7	49.4	48.5	45	±1.2	+0.9
8	49.2	48.5	45	±1.2	+0.7
9	46.7	48.5	45	±1.2	-1.8
10	48.3	48.5	45	±1.2	-0.2
11	48.1	48.5	90	±0.85	-0.4
12	48.1	48.5	90	±0.85	-0.4
13	49.0	48.5	90	±0.85	+0.5
14	48.8	48.5	90	±0.85	+0.3
15	48.3	48.5	90	±0.85	-0.2
16	49.0	48.5	90	±0.85	+0.5
17	49.3	48.5	90	±0.85	+0.8
18	48.0	48.5	90	±0.85	-0.5
19	47.5	48.5	90	±0.85	-1.0
20	48.3	48.5	90	±0.85	-0.2

Table 4.-Comparison of shrinkages of core samples with shrinkages determined commercially of entire bags

Lot number	Bags (Number)	Cores (Number)	Entire bag shrinkage (Percent)	Core sample shrinkage (Percent)	Difference (Percent)	Limits of error (P.=0.95) (Percent)
1	17	34	53.4	53.1	-0.3	±1.4
2	37	74	53.0	54.3	+1.3	±0.9
3	8	16	51.5	51.5	0.0	±2.0
4	5	15	53.5	54.2	+0.7	±2.1
5	8	16	52.5	52.8	+0.3	±2.0
7	15	30	47.6	48.8	+1.2	±1.5
8	5	15	45.2	47.6	+2.4	±2.1
10	13	26	43.3	45.1	+1.8	±1.6
11	10	20	43.9	42.6	-1.3	±1.8
12	12	32	48.3	46.8	-1.5	±1.4
13	5	15	62.7	61.6	-1.1	±2.1
14 & 15	4	20	62.4	63.8	+1.4	±1.8
Totals or averages	139	313	51.1	51.6	+0.5	±0.46

Table 5.-Comparison between shrinkage of core samples and shrinkages determined commercially of entire bales

Clip	Bales (Number)	Cores (Number)	Core sample shrinkage (Percent)	Entire bale shrinkage (Percent)	Difference (Percent)	Limits of error (P.=0.95) (Percent)
1	4	26	51.2	51.4	-0.2	±1.6
2	2	24	53.1	53.0	+0.1	±1.6
3	3	30	56.2	57.1	-0.9	±1.5
4	3	26	56.6	56.4	+0.2	±1.6
5	4	24	59.1	59.5	-0.4	±1.6
6	3	30	57.0	57.8	-0.8	±1.5
7	4	26	52.3	52.4	-0.1	±1.6
8	3	30	52.8	53.8	-1.0	±1.5
9	3	24	54.3	55.8	-1.5	±1.6
Average 1st 9 clips	29	240	54.7	55.2	-0.5	±0.5
10	32	133	45.8	46.3	-0.5	±0.7
10	32	133	46.7	46.3	+0.4	±0.7
10 Average	32	266	46.2	46.3	-0.1	±0.5
Sample average	61	506	50.5	50.8	-0.3	±0.4